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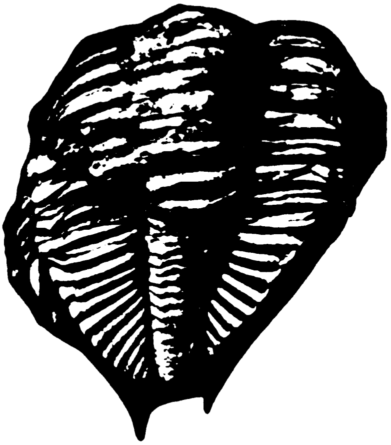

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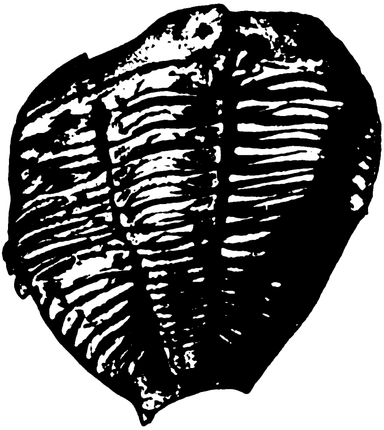

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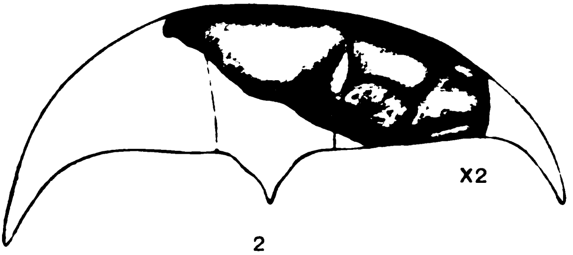

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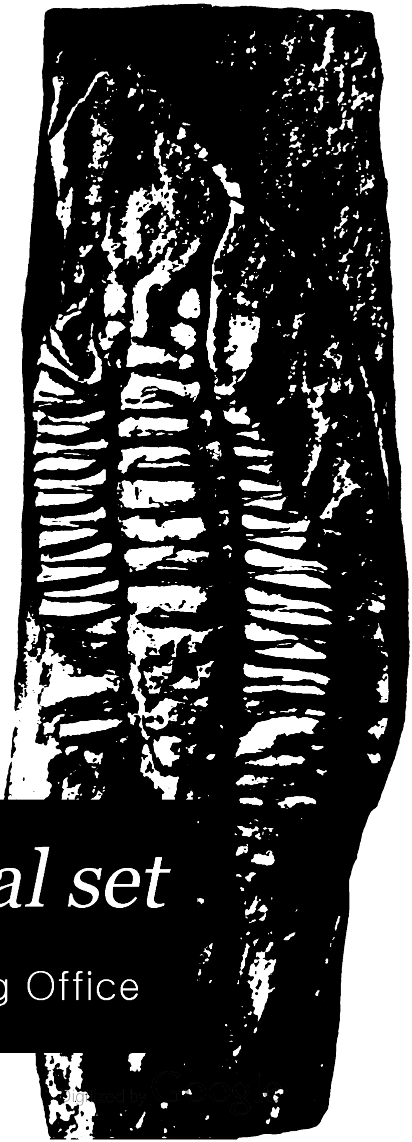

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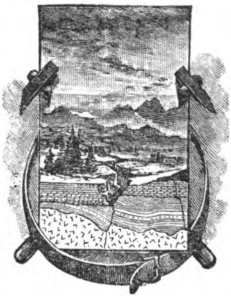

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BULLETIN 508

THE ONONDAGA FAUNA OF THE ALLEGHENY REGION

BY

E. M. KINDLE

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THE ONONDAGA FAUNA OF THE ALLEGHENY REGION.

By E. M. Kindle.

INTRODUCTION.

The importance of the Onondaga limestone as a datum plane was early recognized in New York State. It was easily identified by the peculiar black cherts of some of its beds, and Amos Eaton made important use of it in his early surveys, before the characteristic fossils of this or any other American formation were known. As early as 1839 he wrote to Prof. Silliman regarding its importance to the field geologist as follows:

> I used this rock as the line of reference for other strata, as strangers in New York City use Broadway as a place of reference for other streets. * * * Its vast extent and the important disposition it holds among North American rocks will make it very useful to geological surveyors.[1]

From Hudson River to Lake Erie the Onondaga limestone is represented by a zone of frequently recurring outcrops across central New York State. Passing under Lake Erie, the fauna reappears in rocks of the same lithologic facies in northern and central Ohio, and reaches as far west as Louisville. The most westerly recorded appearance of the fauna is at the Bake Oven, in southwestern Illinois, so that it has an east-west extension of about 1,000 miles. In sharp contrast with this considerable westerly extension of the Onondaga fauna beyond its type region in eastern New York is the comparatively insignificant southerly extension of the fauna and formation as it has been generally recognized. The formation barely crosses Delaware River, according to most of the papers dealing with the stratigraphy of the Devonian in the Allegheny region, which give it a north-south extension of scarcely 200 miles. This insignificant southerly extension of a fauna which has been recognized as so persistent in a westerly direction seems more surprising when it is recalled that nearly all the other faunas characterizing the major divisions of the New York Devonian section have been traced southward from New York entirely across Pennsylvania into the Virginias. Thus, it is seen that the prevailing conception of the Onondaga fauna, which presumes its absence south of New York, gives to it an anomalous position as compared with the other important faunas of the Devonian section of New York. The evidence which I have gathered during several seasons of field work in the Allegheny region indicates that this conception is not well founded, and that the southerly extension of the Onondaga fauna is quite comparable in distance with its westerly extension. Faunal and stratigraphic details of this evidence appear in the following pages. My field studies have shown that the Onondaga fauna in the Allegheny region extends far south of the area in which nearly pure limestones were deposited during Onondaga time, into a region where shale-forming sediments partly or completely dominated those of calcareous type. This fauna has been found in nearly all the sections studied, from New York to Tennessee. Before these sections are discussed, a brief account of the opinions and conclusions of preceding authors on the occurrence of the Onondaga fauna south of New York will be presented.

---

[1] Eaton, Amos, Cherty lime rock, or Corniferous lime rock, proposed as the line of reference for State geologists of New York and Pennsylvania: Am. Jour. Sci., 1st ser., vol. 36, 1839, pp. 62, 64.

HISTORICAL REVIEW.

In the county reports of the Second Pennsylvania Geological Survey the beds lying immediately above the Oriskany are referred to the Marcellus. However, in at least one of the earlier papers dealing with the Devonian section of Pennsylvania, the shale and limestone bands at the base of the Marcellus are referred to the "Upper Helderberg," or Onondaga. Ashburner includes in his section above the Oriskany 60 feet of shale and thin limestone bands which he assigns to the "Upper Helderberg (Post-Meridian) limestone."[1] He gives, however, no paleontologic data bearing on this correlation.

Although some of the earlier writers on the geology of Pennsylvania had included the "Corniferous" (Onondaga) in sections noted in that State, the opinion of Claypole that it was absent seems to have been acquiesced in by almost all later writers. Claypole stated his opinion very positively and asserted that it rested on paleontologic data, and the positiveness of his statement gave it weight with contemporary and succeeding writers. The correlation proposed by Claypole with reference to the Perry County section for the beds above the Oriskany was expressed as follows:

> Overlying the Oriskany sandstone is a series of shales and limestones which paleontological evidence places in the Marcellus division of the Hamilton group.[2]

He does not, however, give the paleontologic evidence on which this correlation rests.

---

[1] Ashburner, C. A., A measured section of the Paleozoic rocks of central Pennsylvania from the top of the Allegheny River coal series down to the Trenton limestone: Proc. Am. Philos. Soc., vol. 16, 1877, pp. 1-19.

[2] Claypole, E. W., A preliminary report on the paleontology of Perry County [etc.]: Second Geol. Survey Pennsylvania, Rept. F2, 1885, p. 64.

Elsewhere Claypole gives several sections showing alternating thin bands of limestone and dark shale, which he states afford as good evidence on stratigraphic grounds for their reference to the Marcellus as to the "Corniferous." This reference he regards as confirmed by the presence of Marcellus fossils in several of the lower beds of shale, but these are not listed. Claypole's opinion of the correlation of this limestone with the Onondaga is expressed in the following quotation:

> The limestone in question [thin beds in lower "Marcellus"] has been regarded as the representative of the Corniferous formation of the New York series, solely on account of its position at the base of the Marcellus black shale. But no trace of the great deposits of flint which characterize the horizon in New York are found in Perry County. Nor have any Corniferous fossils afforded the paleontologist satisfactory evidence of the correspondence of the two strata.[1]

Four years after the publication of the Perry County report the catalogue of the State Museum collections appeared, which contains Claypole's lists[2] of Perry County fossils by localities. This catalogue includes several short lists of fossils from strata variously designated "Marcellus limestone," "Marcellus beds," "Marcellus shale," or "Marcellus formation." These lists are composed largely of unnamed species and species without stratigraphic significance, like *Atrypa reticularis* and *Ambocœlia umbonata*. They contain also the species *Anoplotheca acutiplicata* [3] and *Dalmanites myrmecaphorus?*.[4] As they include these two Onondaga species, Claypole's lists can hardly be said to support his contention that the Onondaga is absent from the Perry County section.

In 1889 T. Rupert Jones described two new species of ostracodes from beds overlying the Oriskany in Perry County, Pa. Accepting Claypole's opinion of the age of these beds Jones refers them to the "noncalcareous shale of the Marcellus limestone." [5]

Lesley[6] did not agree with Claypole's declaration that the Onondaga formation was unrepresented in Pennsylvania. His argument for its presence in central Pennsylvania included no paleontologic evidence, however, and, being based mainly on the principle of the supposed parallelism of the strata, has received much less consideration than the opposite view, advanced by Claypole.

All the recent writers who discuss or refer to the lower part of the Devonian section of Pennsylvania have followed Claypole in assuming that the Onondaga formation and fauna are absent from Pennsylvania sections which expose the lower part of the Devonian, except in the immediate vicinity of the New Jersey boundary. This view is expressed by Ulrich and Schuchert in their paper on Paleozoic seas and barriers.[1] These authors conceived that land surfaces existed throughout the "Cumberland basin from the end of Oriskany time to the initiation of Marcellus sedimentation."

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[1] Op. cit., p. 261.

[2] Pennsylvania Geol. Survey, Rept. D3, 1889, pp. 123, 174.

[3] Idem, p. 171.

[4] Idem, p. 131.

[5] Jones, T. R., On some Paleozoic ostracodes from Pennsylvania: Am. Geologist, vol. 4, 1889, p. 338.

[6] Geol. Survey Pennsylvania, Summary Rept., vol. 2, 1892, pp. 1143-1195.

Schuchert's first paleographic map of Onondaga time[2] limits the Onondaga sea to the northern third of the State, the region of the present outcrops of the lower part of the Devonian and the territory to the south and southeast of them being shown as a land area in Onondaga time. In a later map of the "Middle Onondaga" sea by Schuchert[3] its southern shore is drawn somewhat farther south but still well to the north of the Maryland line.

In discussing the Lower Devonian formations of Maryland Schuchert[4] states that "during Upper Oriskany time sedimentation was again general and continued until the close of the Maryland Oriskanian. Then a land condition prevailed in the basin south of middle Pennsylvania throughout Esopus and Onondaga time."

Both Prosser[5] and O'Harra[6] have considered the lower part of the shale formation that follows the Oriskany sandstone in Maryland as representing in a general way the Marcellus of New York, with which they correlate it.

Prosser[7] reports 21 species, without listing them, from the lower 500 feet of the Romney shale of Maryland and concludes that the "correlation of this Maryland black shale with the Marcellus of New York appears to be fairly well sustained." In this paper Prosser[8] divides the Romney formation of Maryland into two members, called Hamilton beds and Marcellus shale.

In writing the history of Maryland during Paleozoic time Willis assumed that the eastern shore of the Onondaga sea lay somewhere west of the Allegheny Mountains. He regarded the whole of the Romney or "black shale" as of later age than the Onondaga, and stated[9] that "its distribution corresponds to an eastward and southeastward migration of the coast from the shore of the Corniferous gulf over the low marshes of Appalachia."

Schuchert also assumed a hiatus at the top of the Oriskany—a break extending over southern Pennsylvania and across Maryland—as he indicates by the statement that no Esopus, Schoharie, or Onondaga deposits occur in Maryland or farther south.[1]

---

[1] Rept. New York State Paleontologist for 1901, 1902, p. 652.

[2] Schuchert, Charles, On the faunal provinces of the Middle Devonic of America and the Devonic coral subprovinces of Russia, with two paleographic maps: Am. Geologist, vol. 32, 1903, Pl. XX.

[3] Schuchert, Charles, Paleogeography of North America: Bull. Geol. Soc. America, vol. 20, 1910, pl. 75.

[4] Schuchert, Charles, On the lower Devonic and Ontaric formations of Maryland: Proc. U. S. Nat. Mus., vol. 26, 1903, p. 114.

[5] Prosser, Charles, Description and correlation of the Romney formation of Maryland: Jour. Geology, vol. 12, 1904, pp. 361–372.

[6] O'Harra, C. C., The geology of Allegany County: Maryland Geol. Survey, Allegany County, 1900, p. 103.

[7] Op. cit., p. 364.

[8] Idem, pp. 362–367.

[9] Willis, Bailey, Maryland Geol. Survey, special publication, vol. 4, pt. 1, 1900, p. 60.

In the area mapped by N. H. Darton in Virginia and West Virginia the lowest beds of the Romney, which I refer to the Onondaga, were considered to represent the Marcellus. Concerning the fossils in the lower part of the Romney, Darton[2] states: "Those in the lowest beds comprise some species characteristic of the Marcellus."

The papers of J. J. Stevenson[3] are among the first contributions to the correlation of the rocks of southwestern Virginia with those of New York. The Chemung fauna is the earliest Devonian fauna of which he furnished definite evidence.[4] Although he referred the shales below the strata containing the Chemung fauna to the Hamilton,[5] he recorded no Hamilton fossils. The "Corniferous" (Onondaga) he stated to be absent from the area studied by him in southwestern Virginia.[6]

The earliest suggestion of an Onondaga horizon in Virginia known to me appears in a paper by H. S. Williams,[7] who says:

> The next question arising was as to the age of the base of the black shale. The study of the Big Stone Gap sections also threw light on this problem. On the Kentucky side of the Cumberland Channel, as well as on the Appalachia side, there are frequently represented at the base of the black shales beds of brown iron ore. About Big Stone Gap this brown ore contains corals which appear to be of Corniferous age, and below is a sandstone capping the Helderberg limestone. At a single locality, under the woolen mill on the bank of the east branch of Powell River east of Big Stone Gap, in the place of the ore the limestone is quite filled with corals in place, followed immediately by the black shales with no intervening iron ore. This seems to fix the date of the beginning of the black shales for this region at an horizon closely corresponding to that of the Marcellus shale in the New York section.

As no evidence in support of this opinion beyond that contained in the above lines appears in Williams's paper, it may be regarded as having more suggestive than evidential value.

Four quadrangles in southwestern Virginia, mapped by M. R. Campbell,[8] include a portion of the territory in which the Onondaga fauna occurs. Although Campbell makes no specific mention of this fauna and was evidently not aware of its occurrence in the region, unlike some of the authors mentioned in this review, he does not deny its presence. On the contrary, his columnar sections indicate no stratigraphic break within the Devonian and hence provide for the possible discovery of any one or all of the Devonian faunas.

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[1] Proc. U. S. Nat. Mus., vol. 26, 1903, p. 422.

[2] Monterey folio (No. 61), Geol. Atlas U. S., U. S. Geol. Survey, 1899, p. 4.

[3] Notes on the geology of Wise, Lee, and Scott counties, Va.: Proc. Am. Philos. Soc., vol. 19, 1882, pp. 87-107; A geological reconnaissance of parts of Lee, Wise, Scott, and Washington counties, Va.: Idem, pp. 219-262; Notes on the geological structure of Tazewell, Russell, Wise, Smythe, and Washington counties of Virginia: Idem, vol. 22, 1885, pp. 114-160.

[4] Proc. Am. Philos. Soc., vol. 22, 1885, p. 139.

[5] Idem, p. 140.

[6] Idem, vol. 19, 1882, p. 233.

[7] On the southern Devonian formations: Am. Jour. Sci., 4th ser., vol. 3, 1897, p. 399.

[8] Estillville (No. 12), Pocahontas (No. 26), Tazewell (No. 44), and Bristol (No. 59) folios, Geol. Atlas U. S., U. S. Geol. Survey.

The sections studied in my earlier work in the Allegheny region in Pennsylvania did not extend down to the horizon of the Onondaga limestone or the Marcellus shale. Some of the sections which were studied in Virginia in this earlier work, however, included what Williams [1] considered, on rather meager evidence, it must be admitted, an early Middle Devonian horizon. Grabau,[2] who found this evidence unfavorable to his hypothesis of a southward transgression of black shale in the Allegheny region, concluded that "the evidence adduced points to an early Upper Devonic age of the black shales at Hot Springs, rather than a lower Middle Devonic, as advocated by Williams." Farther north in Maryland, however, where the theory of the southward transgression of the black shale must assume an earlier age for these beds than in central Virginia, the black shale is, according to Grabau, "clearly of the age of the Marcellus of New York and in part it also represents the Onondaga." For the statement that the black shale in part represents the Onondaga no evidence is offered. Though correct, this opinion appears to have been deduced from the broader inference of the southward transgression of the black shale.

Schuchert,[3] in a review of the paper by Williams and Kindle, just cited, stated that the faunules in question "are decidedly more Marcellus than Onondaga." Schuchert's unwillingness to admit the Onondaga age of any part of the Virginia section appears to have been due in part to his doubt of the correctness of my identification of *Anoplotheca acutiplicata*. With reference to this identification Prosser,[4] in a later review of the same paper, regarded this identification as probably correct, "for the same species occurs near the base of the black shale or Marcellus member of the Romney formation in western Maryland. The Maryland specimens were examined by Dr. John M. Clarke, so that no question can be raised regarding their specific identity." It should be stated here that the collections on which the determination of the Onondaga age of the Virginia sediments was based were small and not fairly representative. In succeeding pages it will be shown that *Anoplotheca acutiplicata* and other Onondaga species occur not only in Virginia but in the West Virginia, Maryland, and Pennsylvania sections to the north.

R. S. Bassler [5] has published several sections in southwestern Virginia, which include the beds below the black shale. Although his paper is economic, it gives much valuable detail concerning the faunas of the limestones. The paleontologic notes do not extend to the Onondaga fauna, however, and the paper is mentioned here only because of its contribution to our knowledge of the beds which lie below those containing the Onondaga fauna.

---

[1] Williams, H. S., and Kindle, E. M., Contributions to Devonian paleontology, 1903: Bull. U. S. Geol. Survey No. 244, 1905.

[2] Grabau, A. W., Bull. Geol. Soc. America, vol. 17, 1906, p. 609.

[3] Am. Jour. Sci., 4th ser., vol. 19, 1905, p. 461.

[4] Am. Geologist, vol. 36, 1905, p. 50.

[5] The cement resources of Virginia west of the Blue Ridge: Bull. Virginia Geol. Survey No. 2-A, 1909, pp. 258-273.

The latest reference to the Onondaga fauna in the Allegheny region which has come under my notice occurs in a paper by Weller,[1] whose observations, however, are of a generalized character, intended to summarize the more salient points in the several papers which have appeared on the faunas discussed. Weller's remarks on the geographic distribution of the Onondaga fauna in the Appalachian region differ from my conclusions in much the same way as those of the other authors already noted. It should be added, however, that Weller's paper does not undertake to give any new data on the region discussed, and the discrepancy between his conclusions and mine, as well as that between some other statements which have been noted and the facts which will be cited, can probably be traced back to Claypole's declaration that the Onondaga fauna is absent in most of the region south of New York.

GENERAL STRATIGRAPHIC RELATIONS.

Before considering the stratigraphic relations of the beds and fauna which constitute the subject of this paper, it is desirable to refer briefly to the general conditions controlling sedimentation during the Devonian period in what may be called the Allegheny province. The greater part of the province was occupied during Devonian time by a broad arm of the sea, known as the Appalachian Gulf. Along the eastern border of this gulf were deposited the 5,000 to 10,000 feet of Devonian sediments found in the Allegheny region.

Although the general tendency of earth movement in this region was toward subsidence, there were occasional intervals of uplift when the sea became shallow, as is shown by the ripple marks of the Portage. At other stages, such as the Genesee, with its fine black shales without wave marks, there was evidently deeper water. The great thickness of clastic sediments comprised in the Devonian system of this region was derived largely from the land area that lay immediately east of the Appalachian Gulf and is known as Appalachia.

Faunal and stratigraphic studies in the Appalachian province should proceed with a clear recognition of the essential factors which determined in large degree the character of the faunas and sediments. The most important factors controlling the uniformity of a fauna are temperature, ocean currents, character of sedimentation, depth of water, food supply, and land barriers. Any considerable change in any one of these factors will give rise to a corresponding difference in the character of a fauna. These factors differ in relative importance in different regions. The factors of prime importance with reference to the character of the formations are source of materials, distance from shore line, and means of transportation. It is clear that land areas of crystalline rocks will afford sediments of different types from those composed of noncrystalline rocks, and that rivers in limestone lands will carry to the sea sediments differing widely from those of rivers that are eroding in areas occupied by sandstone or quartzite. Likewise we may expect the sediments representing any one interval of time not only to differ with difference in their distance from the shore line of the sea in which they were deposited but also to differ according to their distance from river mouths and, to some extent, with reference to their relation to ocean currents. Allusion to principles so elementary as these might appear superfluous were it not for the fact they have obviously been lost sight of by the authors of some papers on stratigraphy, who appear to suppose that differences between contemporaneous faunas can be accounted for only by assuming the presence of land barriers. Quite as often we find the naïve reasoning that the absence in a particular area of a type of sediments which is generally characteristic of a particular formation indicates there a hiatus representing the time during which that formation was deposited in the region where its peculiar type of sediment is found. Such an assumption fails to take cognizance of the important stratigraphic principle that lithologic character remains uniform only over the area in which the sediments were uniform in character and amount. It is to be expected that the amount and kind of sedimentation will vary at a much more rapid rate in a direction normal to the coast than parallel to it. The areas of uniformity in sedimentation are in general parallel to the old shore lines of the Devonian sea.

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[1] Weller, Stuart, Correlation of the Middle and Upper Devonian and the Mississippian faunas of North America: Jour. Geology, vol. 17, 1909, p. 261.

Many of the Devonian formations of New York and the Allegheny region well illustrate this principle, thinning and grading laterally into very unlike formations of finer texture toward the west, while retaining a uniform character for a much greater distance toward the south and southwest. The Hamilton formation affords a notable example. In eastern Pennsylvania it includes much coarse sandstone and even some conglomerate. Farther west every trace of these coarse clastic materials has disappeared from the sections, and the thickness of the formation has been reduced about one-half. In the eastern ranges of the Alleghenies, however, sandstones are conspicuous in the Hamilton in three States.

The Devonian formations occur in broad belts, crossing New York from east to west. In following these formations westward across the State of New York the faunal as well as the lithologic facies of some of them have been found to change completely. The contrast between the lithologic facies of the Portage formation in eastern and in west-central New York is less striking than that between its faunal facies in the two districts, which are totally unlike.

Although the Devonian formations as a rule retain their lithologic and faunal integrity for a much greater distance parallel to the old coast line of the Appalachian gulf than at right angles to it, still nearly all of them undergo great changes, both lithologic and faunal, in their southern extension. The lithologic peculiarities of formations which at the north are sharply differentiated tend to converge toward a uniform type of sediments at the south.

To illustrate this differentiation of the Devonian sediments into a greater number of lithologic units at the north than at the south, the Devonian geologic section of New York and of Maryland, as given by the geological surveys of the two States, may be compared. The New York section shows fourteen distinct divisions,[1] not including some minor subdivisions, whereas the Maryland section shows but five subdivisions.[2] This great difference in the number of formations recognized in New York and Maryland is due primarily neither to comparative incompleteness of the Maryland sedimentary record nor to lack of discrimination on the part of the Maryland geologists, but it represents a tendency to lithologic uniformity toward the south, which begins to be prominent only in Maryland. This tendency of the Middle Devonian formations above the Oriskany sandstone to lose their lithologic distinctions is shown in the following table, which indicates their stratigraphic relations and geographic distribution in the Allegheny region. With the exception of the Onondaga, which has generally been considered absent south of New York, the stratigraphic nomenclature of the table is that which has been used in United States Geological Survey folios and recent State Survey reports. This table illustrates vividly the preceding remarks regarding the well-marked lithologic differentiation of the Devonian section at the north and its slight differentiation at the south and shows also the relation of the Onondaga fauna and formation to other formations or lithologic groups.

---

[1] Mem. New York State Mus. No. 3, 1900, p. 9.

[2] Maryland Geol. Survey, Allegany County, 1900, pp. 94–109.

Table showing decreasing differentiation of formations in equivalent beds from northeast to southwest.

New York.		Pennsylvania.	Maryland.	West Virginia.	Virginia.	
Schoharie.	Port Jervis.				Northern part.	Southwestern part.
Hamilton. Marcellus. Onondaga. Schoharie. Esopus.	Esopus.	Hamilton. Marcellus. Onondaga.	Romney. Onondaga shale member of Romney.	Romney.	Romney.	Chattanooga. Onondaga limestone member of Chattanooga.
Oriskany.		Oriskany.	Oriskany ("Monterey") sandstone.	Oriskany ("Monterey") sandstone.	Oriskany ("Monterey") sandstone.	Giles.[a] Hancock.[a]

[a] The intention here is not to correlate either the Giles formation or the Hancock limestone with the Oriskany sandstone, as their relative positions in the table suggest, but only to indicate their relation in the section to the Chattanooga shale and Onondaga limestone member.

The formational nomenclature which has been used in State and Federal reports relating to the Allegheny region illustrates the salient fact that the formations tend to converge toward a common lithologic type southward, but it is too much generalized and falls considerably short of representing all the facts with respect to subdivisions that can and should be discriminated. This nomenclature notably fails to recognize the important formation and fauna which constitute the subject of this paper. This formation, which will be called the Onondaga shale member of the Romney over most of the southern region, comprises in Pennsylvania a series of dark limestones and interbedded shales which lie between the Oriskany sandstone below and the fissile black carbonaceous shales of the Marcellus above. These stratigraphic boundaries are constant from the New Jersey line to and beyond James River in Virginia. The drab or dark shale is generally the predominant element of these strata in Pennsylvania, but in certain areas the limestones are the more prominent of the two, and some of these are pure enough to be burned for lime. Generally, however, the limestone bands carry a large percentage of argillaceous matter. After prolonged leaching these impure limestones acquire an appearance which affords but little suggestion of their original calcareous nature. Southward from Pennsylvania the calcareous element becomes less prominent until southwestern Virginia is reached; here over a small area we find a nearly pure limestone. The presence of limestones in the beds holding the Onondaga fauna, however, is not the only physical characteristic which distinguishes them from the fissile black shales above.

Another important distinguishing lithologic feature appears to have been overlooked. In Maryland, West Virginia, and Virginia, where the limestone is somewhat less prominent than in Pennsylvania, these lower shales, though variant in color, are noticeably lighter colored than those above the horizon at which calcareous beds are conspicuous. These upper strata are almost everywhere black, very fissile shales. The lower shales (Onondaga), on the other hand, comprise olive green, gray, buff, or cream colored beds, interbedded with a minor amount of black shale. These lower black shales differ fundamentally from the upper series in being generally though not invariably nonfissile and of the blocky type. The black shale in the lower terrane does not split or cleave in one direction more easily than in another. It shows in many sections much the same difference from a fissile shale that is shown by a piece of chalk or clay.

The fauna which characterizes these beds has up to the present time remained almost totally unknown, and this fact and the resulting erroneous assumption that these beds were a part of the Marcellus shale have probably caused the geologists who dealt with them south of the Pennsylvania-Maryland boundary to fail to recognize the Onondaga in their nomenclature. The geologists of the Pennsylvania State Survey, however, though unacquainted with the fauna of these beds, did not fail to recognize the fact that they constitute a lithologic unit distinct from either the beds above or those below. In Huntington County Ashburner[1] as early as 1878, recognized the limestones and shales between the Oriskany and the Marcellus shale as a distinct formation and correlated it with the "Upper Helderberg" (Onondaga) of New York. In two counties in Pennsylvania I. C. White[2] used a local name for these beds, calling them the Selinsgrove lower limestone and shale. Claypole,[3] who supposed the strata under consideration to be characterized by a Marcellus fauna, divided his "Marcellus" formation into what may be considered three separate members, which he called Marcellus black shale, Marcellus limestone, and Marcellus lime shales.

These observations will suffice to show that though the Pennsylvania geologists were not familiar with the Onondaga fauna, they recognized the stratigraphic distinctness of the beds holding that fauna, and correctly correlated, at least one of them, on stratigraphic grounds alone, with the Onondaga of New York. The geologists working south of Pennsylvania have not entirely failed to recognize the distinctive lithologic features of these strata, although heretofore these beds have found no place in the formational nomenclature of the region. The geologic descriptions of the lower portion of the Romney shale in Maryland show the presence of limestones at a horizon corresponding to that of the lime shale which the Pennsylvania geologists have all recognized at the base of the Marcellus. From Prosser[1] I quote the following regarding the Maryland section:

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[1] Second Geol. Survey Pennsylvania, Rept. F, 1878, p. 223.
[2] Idem, Rept. T3, 1885, p. 114.
[3] Idem, Rept. F2, 1885, p. 62.

> About 150 feet from the bottom of the formation there are several bluish-gray fossiliferous limestone bands. These are apparently never absent, although in the well-exposed Williams Road section none of them can be seen. This is perhaps due to the effect of weathering, as certain evidence indicates their probable presence. These bands are individually rarely 3 feet, usually less than 1 foot, thick, but the total thickness in the best-exposed sections is more than 20 feet.

The above statement tallies with the testimony of the Pennsylvania geologists concerning the conditions at this horizon in Pennsylvania, as indicating a limestone and shale formation near the base of the Romney shale in Maryland. I would add to it the statement that the shales in this lower 100 to 150 feet in Maryland are generally of much lighter color than those of the Marcellus, in many places drab or olive. Those that are black are usually of the blocky type, without cleavage, and thus present marked contrast to the fissile Marcellus shale higher up.

In West Virginia and Virginia the distinctive lithologic features of these strata were partly recognized by the geologists who wrote the Piedmont and Franklin folios, although they did not, like the Pennsylvania geologists, treat these beds as separate members or formations. Darton and Taff[2] describe these beds in the Piedmont area as follows: "The formation [Romney] includes occasional thin beds of fossilliferous limestone not far from its base."

A very similar description is given by Darton[3] for the same beds in the adjacent area to the south.

Like Prosser's notes on the limestones in the lower Romney of Maryland, these observations on the limestone bands in the lower Romney of Virginia and West Virginia need to be supplemented by a statement of the lithologic characters of the shales associated with these limestone bands, which distinguish them from the shales of the Marcellus portion of the Romney.

Darton[4] evidently recognized the same beds still farther south, in the Staunton quadrangle, for he states that "The formation includes occasional calcareous streaks not far from its base." He entirely omits to mention, however, other distinguishing lithologic features of this part of the Romney which I have fully shown in my section at Bells Valley, Va. (See pp. 43-45.)

The quotations given above indicate that the geologists who have written on the Romney shale recognized at least some of the distinctive lithologic characters of the beds holding the Onondaga fauna. In this connection it is necessary to consider briefly the definition and lithologic features of the Romney shale and its relations to the Onondaga. The type locality of the Romney shale is Romney, W. Va. The name was proposed by Darton[1] for a set of beds composed mainly of shales lying between the "Monterey" (Oriskany) sandstone below and the Jennings formation above.[2] The Jennings has since been shown to carry the Portage and Chemung faunas. As thus defined, the Romney shale includes the beds holding the Onondaga fauna as well as the stratigraphic and faunal equivalents of the Marcellus shale and the Hamilton formation. Prosser[3] has shown that the Romney includes the equivalents of the Hamilton and Marcellus formations of the New York section. It will be shown in this paper that it includes also the equivalent of the Onondaga limestone.

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[1] Maryland Geol. Survey, Allegany County, 1900, p. 105.

[2] Piedmont folio (No. 28), Geol. Atlas U. S., U. S. Geol. Survey, 1896, p. 3.

[3] Franklin folio (No. 32), Geol. Atlas U. S., U. S. Geol. Survey, 1896, p. 3.

[4] Staunton folio (No. 14), Geol. Atlas U. S., U. S. Geol. Survey, 1894, p. 2.

The beds included in the Romney in Maryland and Virginia, both north and south of the type locality, are largely shales, forming valleys in which the limits of the different members can not be very readily observed. In the middle and southern Virginia region there is no such well-marked transition from the fissile black shale to the Hamilton above as can be easily recognized farther north, and it becomes most difficult to fix the precise limits of the beds which are to be correlated with the Marcellus and the Hamilton of Pennsylvania and New York. In much of this region, therefore, Romney shale becomes a useful term. It is a broader term than any of the formation names used in the New York section, for it includes the Onondaga, Marcellus, and Hamilton faunas. Hence, it is to be considered for the Virginia and Maryland region the approximate equivalent of the Ulsterian of Clarke[4] and the Erian of Schuchert.[5] In the more easterly sections, and toward the north, where the earlier named and more narrowly limited New York formations represented in the Romney can be discriminated on both faunal and lithologic evidence, these smaller units should be used.

As the eastern shore line of the Devonian sea is approached near the Potomac, sandstones are found to become a prominent element at the Hamilton horizon of the Romney, as they do in eastern Pennsylvania. This sandstone element is well developed in the Hedgesville section in West Virginia. Farther west and south both the faunal and the lithologic differences between the upper and lower portions of the Romney are less marked, as already pointed out.

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[1] Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, 1892, pp. 10-18.

[2] In the original definition of the Romney shale Darton (idem, pp. 17-18) states that the formation contains "Corniferous" species, but as none of the species cited are characteristic of the "Corniferous" this statement probably resulted from a typographic error.

[3] Prosser, C. S., Jour. Geology vol. 12, 1904, pp. 361-372.

[4] Mem. New York State Mus. No. 3, 1900, p. 9.

[5] Bull. Geol. Soc. America, vol. 20, 1910, p. 541.

Where the lithologic differentiation is least prominent, however, the three types of faunas found in the Romney shale are still limited to the same relative parts of the section as farther north. The lowest of these faunas is confined to a sedimentary series which includes, mainly, alternating drab or olive-green and black clay shales, with a few thin bands of impure limestone. Upon these lies a series of generally fissile black shales, with comparatively few drab or light-colored shales. The uppermost division includes drab or sandy shales and sandstones carrying the Hamilton fauna. The lowest of these divisions, the Onondaga, is more persistent in its lithologic characters than the other two divisions of the Romney. Even where these two upper divisions have become nearly indistinguishable by either their lithology or their faunas, the drab or dark shales with limestone bands and their distinctive Onondaga faunas may still be easily recognized. As the term Romney shale is useful to designate collectively these three recognizable divisions in parts of Maryland, West Virginia, and Virginia, it appears expedient to treat the Onondaga shale in that region as a member of the Romney shale.

In Virginia the limestone of the Onondaga becomes less and less prominent toward the southwest, almost disappearing in the James River region but reappearing in southwestern Virginia. South of James River the calcareous beds below the Marcellus, though more attenuated, can still be distinguished in good sections. In this southwestern region four quadrangles have been mapped by M. R. Campbell and a number of sections have been described by Williams and Kindle, but it appears that these geologists overlooked the Onondaga in this region, for they make no specific reference to it in their published work.[1] It is present, however, over at least a portion of this southwestern area. At Big Stone Gap the Onondaga fauna occurs in a cherty limestone, 8 feet thick, which separates the black shale of the Chattanooga formation from the Hancock limestone, and is included in the Chattanooga as mapped. This limestone does not differ in physical character from typical exposures of the Onondaga limestone in New York State, but, being too thin to discriminate on maps and having been previously included in the Chattanooga shale as there defined, it will be treated as a member of the Chattanooga.

Summarizing the evidence which has been presented relative to the treatment of the beds holding the Onondaga fauna as a lithologic unit, I may say that I have shown, from the evidence of geologists, who know little or nothing about the faunas involved, that the Devonian section of the Allegheny region includes a set of calcareous shales which occupy a definite and uniform stratigraphic position from the New Jersey-Pennsylvania line to James River in Virginia. Within

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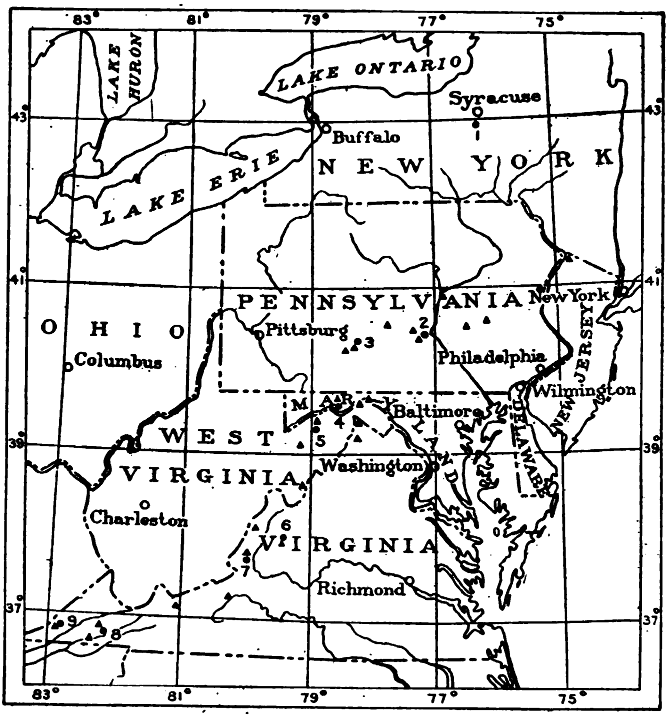
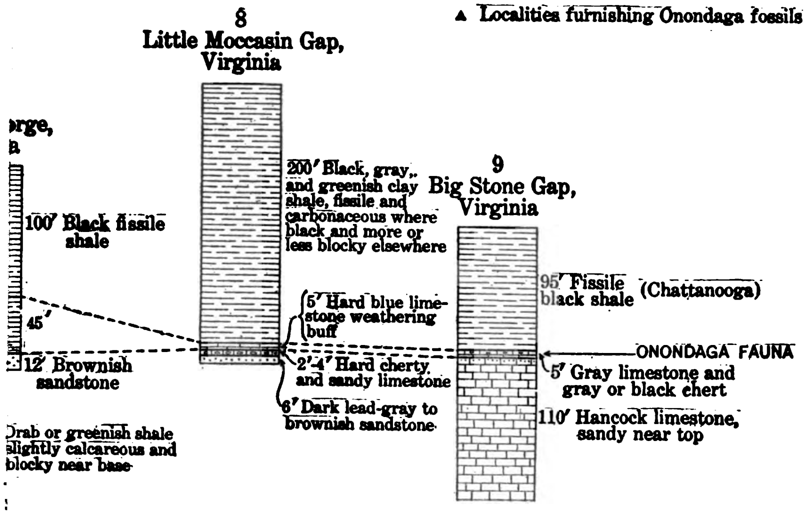
[1] Folios 12, 26, and 59, Geol. Atlas U. S.; Bull. U. S. Geol. Survey No. 242



● Sections on chart

▲ Localities furnishing Onondaga fossils


rge,
a
100′ Black fissile shale
45′
12′ Brownish sandstone
rab or greenish shale
lightly calcareous and
locky near base
8
Little Moccasin Gap, Virginia
200′ Black, gray, and greenish clay shale, fissile and carbonaceous where black and more or less blocky elsewhere
5′ Hard blue limestone weathering buff
2′-4′ Hard cherty and sandy limestone
6′ Dark lead-gray to brownish sandstone
9
Big Stone Gap, Virginia
95′ Fissile black shale
(Chattanooga)
ONONDAGA FAUNA
5′ Gray limestone and gray or black chert
110′ Hancock limestone, sandy near top

.A.

this geographic district they lie above the Oriskany sandstone and below the fissile black shale, which, farther north, is generally called Marcellus, and which represents a part of the Romney south of Potomac River. The same beds continue nearly to the Tennessee line, but become much thinner. They lie below and grade into black shales, like those found farther north, except in the vicinity of Big Stone Gap, where the change to the overlying black shale is abrupt, but in this southwestern region they generally rest on rocks that do not appear to be of Oriskany age. These shales which lie at the base of the Devonian shale series differ from the fissile black shales immediately above them not only in being somewhat calcareous but in being uniformly lighter in color, locally in part cream colored, and in being in many places nonfissile.

In the preceding discussion I have sought to show chiefly the lithologic and stratigraphic grounds for treating the beds under discussion as a distinct subdivision. Lest it might appear that the proposed discrimination of these beds as a distinct unit is based on their faunal rather than their lithologic distinctness, I have introduced into this general discussion of the stratigraphy the testimony of other geologists whose judgment in this respect was certainly not biased by a knowledge of the fauna. The strength and the relations of this evidence can best be shown by assembling a few representative sections, which, for the reason just stated, are drawn as far as possible from papers already published. The accompanying chart of representative sections (Pl. I) shows that the stratigraphic relations of these beds are uniform from Pennsylvania to the middle portion of Virginia. The Allegheny sections are placed beside a section showing the Onondaga limestone and adjacent formations as they are developed in the type region of the Onondaga in New York State. The similarity of the stratigraphic position of the formation in central New York and in much of the Allegheny region is obvious.

The sections on the chart are based on published and unpublished data obtained from the sources indicated below:

1. Onondaga County, N. Y. After Clarke, J. M., and Luther, D. D., Bull. New York State Mus. No. 82, 1905.
2. Perry County, Pa. After Claypole, E. W., Second Geol. Survey Pennsylvania, Rept. F2, 1885.
3. Huntingdon, Pa. After White, I. C., and Ashburner, C. A., Second Geol. Survey Pennsylvania, Rept. F, 1878; Rept. T3, 1885.
4. Maryland. Generalized after Prosser, C. S., Maryland Geol. Survey, Allegany County, 1900.
5. West Virginia. Kindle.
6. Bells Valley, Va. Kindle.
7. Clifton Forge, Va. Kindle.
8. Little Moccasin Gap, Va. Kindle.
9. Big Stone Gap, Va. Kindle.

DETAILED STRATIGRAPHY.

NEW YORK.

A brief account of the stratigraphy of the Onondaga and closely associated formations in southeastern New York is introduced here for convenience of comparison and correlation with the Allegheny sections.

In the Helderberg Mountains of eastern New York the Onondaga limestone exhibits its typical development, and in no other region can its relations to the adjacent formations be studied to greater advantage. These formations are exposed in the face of the bold and imposing cliffs of the Helderberg escarpment, which rises abruptly more than 1,000 feet above the broad valley of the Hudson. This is classic ground to American geologists, having served as the geologic nursery of such men as Eaton, Mather, Emmons, Conrad, Hall, and Agassiz. The writings of these authors, as well as many later papers, have contributed to the elucidation of the geology of the Helderberg Mountains. This area, therefore, serves well as a starting point for stratigraphic studies in the much less well-known region farther south. As a standard for comparison I may introduce here a typical section of the Devonian seen at and south of Countryman Hill, near the north end of the Helderberg Mountains. The greater part of this section, except the Marcellus and Hamilton formations, is exposed along the highway immediately west of the village of New Salem. The thicknesses given for the Hamilton and Marcellus are based on Prosser's Clarksville section,[1] which was taken a few miles south of the New Salem section.

Section in the Helderberg Mountains, southwest of Albany.

	Feet.
Hamilton: Brownish arenaceous shales and sandstones with black arenaceous shales in lower 200 feet	490
Marcellus: Black argillaceous shales with dark, slightly calcareous sandstones. This formation shows gradual transition to the arenaceous shales of the Hamilton	300
Onondaga: Massive light-gray limestone with considerable chert locally. Brachiopods and corals common but not abundant	100
Schoharie grit: An impure dark-gray limestone which weathers to a buff porous sand rock	3
Esopus shale: Blackish or dark-gray arenaceous shales which contain few or no fossils except *Spirophiton cauda-galli*	121
Oriskany: Coarse sandstone varying from dark quartzitic rock to soft brownish sandstone. Fossils abundant	3
Becraft limestone: Gray coarse-grained heavy-bedded limestone with numerous fossils	13
New Scotland limestone: Drab calcareous shale with some intercalated beds of blue limestone. Fossils abundant	120

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[1] Prosser, C. S., and Rowe, R. B., Stratigraphic geology of the eastern Helderbergs: Fifty-first Ann. Rept. New York State Mus., vol. 2, 1899, p. 346.

	Feet.
Coeymans limestone: Massive bluish-gray limestone.............	50
Manlius limestone: Dark-blue thin-bedded fine-grained limestone. Tentaculites and ostracodes abundant..........................	46

The descriptions of the above section are taken from my notes, but the thicknesses are quoted from the carefully measured and more detailed sections published by Prosser and Rowe.[1] The total thickness is indicated for each of the formations represented in the section except for the Hamilton, only the lower portion of which is present at the eastern margin of the Helderberg Mountains. The thickness given for the Hamilton represents only the portion exposed near Clarksville,[2] a few miles south of Countryman Hill, which is perhaps little more than one-third of its entire thickness. About 4 miles west of New Salem nearly the entire Hamilton section is exposed in the high hill just south of the village of East Berne. Here it is mainly a sandstone formation, the interbedded shales representing a minor element.

Clarksville is the best-known locality for Onondaga fossils in the Helderberg region. The following is a list of the Onondaga fauna from this locality recorded by Prosser and Rowe.[3]

Meristella unisulcata (Con.) H....	[4] r
Leptæna rhomboidalis (Wilck.) H. & C..........................	r
Atrypa reticularis (Lin.) Dal.....	aa
A. spinosa H....................	aa
Pentamerella arata (Con.) H......	c
Stropheodonta concava H........	r
S. textilis H.....................	rr
Spirifer duodenaria H...........	a
S. macra H. (?)..................	rr
Dalmanites (Coronura) aspectans (Con.) H......................	rr
Phacops cristata var. pipa H......	rr
Platyceras dumosum Con..........	c
Cyrtoceras sp....................	rr
Zaphrentis gigantea (Le Sueur) Edw. & H.....................	rr
Z. corniculum (Le Sueur) Edw. & H...........................	rr
Fenestella biseriata H............	rr

From the Countryman Hill section southwest of Albany the line of outcrop of these formations extends southward parallel to the Hudson to Kingston, thence southwestward to the New Jersey-Pennsylvania boundary at Tristates, N. J.

In the Schoharie Valley, which is the type region of the Schoharie grit, that formation is estimated to be 5 or 6 feet thick, and the Esopus shale below it is from 80 to 90 feet thick.[5] In the northeastern part of the Helderberg region the Schoharie grit and Esopus shale are readily distinguishable, the former being a gray, highly siliceous limestone which weathers to a porous sandstone that is generally fossiliferous, and the latter a drab to blackish siliceous shale without lime, nearly or quite barren of fossils. Farther south, however, the distinctions between these two formations become vague and finally disappear. At Hudson, where these formations comprise, according to Grabau,[1] about 300 feet of "dark chocolate-colored gritty shales," the distinctions between the two are not very well marked and "150 to 200 feet of strata lithically similar to the Esopus but more cleaved are referred to the Schoharie formation, since some of the characteristic fossils have been found in them."[2] Still farther south no line of division can be drawn between the two. At Kingston Van Ingen[3] has applied the name Esopus grit to the entire mass of olive-brown fine-grained argillaceous grit that occupies the interval between the Onondaga limestone and the Oriskany sandstone. These grit beds have here a thickness of about 300 feet.

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[1] Op. cit., pp. 335, 338.

[2] Idem, p. 346.

[3] Idem, pp. 352, 353.

[4] The following abbreviations are used in the fossil lists in this bulletin: a, abundant; aa, very abundant c, common; r, rare; rr, very rare.

[5] Grabau, A. W., Guide to the geology and paleontology of the Schoharie Valley in eastern New York Bull. New York State Mus. No. 92, 1906, pp. 170, 180.

In the vicinity of Kingston and Rondout and southward into New Jersey the Esopus grit contains few fossils except *Anoplotheca acutiplicata,* which can be found at most localities where the formation occurs.

The very gradual transition of the Esopus shale into the Onondaga limestone at Kingston clearly indicates that the Schoharie is not represented by an unconformity in this region, but has become an integral part of the Esopus. With reference to this transition Van Ingen[4] states that "the upper part of the Esopus grit merges into the lower portion of the Onondaga by such gradual changes that no line of demarcation can be drawn."

From the preceding summary of the more important facts concerning the relations of the Onondaga and subjacent formations in southeastern New York it appears that there is no stratigraphic break between either the Onondaga and Esopus or the Esopus and Schoharie. It is probable that sedimentation continued without interruption from the Oriskany into the Onondaga in at least a part of this area.

NEW JERSEY.

The grit series at Tristates, where it passes across the New York-New Jersey boundary, has been treated as a single formation by Weller,[5] who applied to it the name Esopus shale. *Anoplotheca acutiplicata* occurs rather commonly in the formation near the schoolhouse and east of the river road 1½ miles below Tristates.

At Tristates the Esopus is a very hard drab-colored siliceous shale, with slaty cleavage at right angles to the bedding. It weathers into fine splintery fragments. The very uniform character of the material composing it gives no indication of bedding planes where fossils are absent.

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[1] Grabau, A. W., Stratigraphy of Becraft Mountain, Columbia County, N. Y.: Bull. New York State Mus. No. 69, 1903, p. 1069.

[2] Grabau, A. W., Bull. New York State Mus. No. 92, 1906, p. 181.

[3] Van Ingen, Gilbert, Disturbed fossiliferous rocks in the vicinity of Rondout, N. Y.: Bull. New York State Mus. No. 69, 1903, p. 1204.

[4] Idem, p. 1205.

[5] Weller, Stuart, A report on the Paleozoic paleontology of New Jersey: Geol. Survey New Jersey, Paleontology, vol. 3, 1902, p. 102.

The Onondaga limestone, which lies immediately above the Esopus shale, forms a low, narrow ridge separating Delaware and Navesink rivers just above their confluence. The monument marking the junction of the States of New York, New Jersey, and Pennsylvania is located on the point of this ridge. The Onondaga limestone forms the east bank of Delaware River below the Navesink for several miles and outcrops at intervals below Tristates. In this region it is a hard, bluish-gray, slightly impure limestone containing an abundance of chert. At Tristates the Onondaga appears to contain a slightly greater percentage of argillaceous matter than it does farther north, but the difference is slight and the lithologic facies differs but little from that seen in the Countryman Hill section. The Marcellus shale at the top of the Onondaga shows no indication of a lithologic modification such as that which has reduced the Schoharie grit at the base of the Onondaga to an indistinguishable part of the Esopus north of the New Jersey line. The Marcellus continues on into Pennsylvania with the same fissile black shale facies that is seen in the Countryman Hill section.

Fossils are not abundant in the Onondaga limestone near Tristates and those that are present are difficult to extract from the tough cherty limestone. At the mouth of Neversink River, where the Onondaga limestone is well exposed, only two species were found, both characteristic Onondaga forms, namely, *Odontocephalus ægeria* or *O. selenurus* and *Phacops cristata* var. *pipa*. The faunule recorded by Weller[1] from a locality a few miles below Tristates is probably a representative Onondaga faunule for this region. It is as follows:

Zaphrentis sp. undet.
Lingula sp. undet.
Leptæna rhomboidalis (Wilck.).
Schuchertella pandora (Bill.).
Rhipidomella vanuxemi (Hall).
Atrypa reticularis (Linn.).
Spirifer sp. cf. S. varicosus Hall.
Anoplotheca concava (Hall).
Platyceras sp. undet.

Anoplotheca acutiplicata is recorded by Weller from two localities in this region and appears to be a common species of the Onondaga in New Jersey as it is in Pennsylvania.

PENNSYLVANIA.

General conditions.—Near the mouth of Flat Brook Creek the Onondaga limestone crosses to the Pennsylvania side of Delaware River. Geologists[2] have agreed in recognizing the presence of the

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[1] Weller, Stuart, op. cit., p. 104.

[2] Lesley, J. P., Summary Rept. Geol. Survey Pennsylvania, vol. 2, 1892, pp. 170–172. White, I. C., Geol. Survey Pennsylvania, vol. G6, 1882, p. 120. Prosser, C. S., The Devonian system of eastern Pennsylvania and New York: Bull. U. S. Geol. Survey No. 120, 1894, pp. 3, 4.

Onondaga and Esopus[1] formations west of Delaware River in Pennsylvania as far as Stroudsburg, but their presence beyond this point to the southwest has generally been denied, as noted in preceding pages.

Throughout the 150 miles of outcrop of the Onondaga and Esopus formations from Albany, N. Y., to Stroudsburg, Pa., the lithologic and stratigraphic evidence of the identity of these two formations in the innumerable sections which may be studied is so clear and evident as to require no special reference to the paleontologic evidence. In the region southwest of Stroudsburg, however, consideration of both classes of evidence is indispensable to sound conclusions. In nearly all the sections some thin beds of limestone, interbedded with beds of drab gray or black shale, lie above the Oriskany sandstone. The limestones, however, contain characteristic Onondaga fossils, indicating that they were contemporaneous with the nearly pure Onondaga limestone found farther north. Their interbedding with the dark shales clearly shows that the black-shale sedimentation which overspread the entire area of the Onondaga limestone in New York at the end of Onondaga time began in the Allegheny region in Onondaga time.

Stroudsburg section.—At East Stroudsburg, Pa., a few miles west of Delaware River, the Onondaga is still distinctly a limestone formation and exhibits the flint lenses and nodules so characteristic of the formation in New York. This limestone and nearly the entire thickness of the Esopus shale underlying it may be seen in the cut on the Delaware, Lackawanna & Western Railroad one-half mile south of the Stroudsburg station and in the pasture just north of the cut. Onondaga fossils are abundant at the latter locality (station *22a*, Stroudsburg, Pa.) near the spring, where the faunule listed below was collected:

Zaphrentis simplex	c	Chonetes mucronatus	c
Cystiphyllum sp.	r	Cyrtina hamiltonensis	r
Fenestella sp	c	Leptæna rhomboidalis	r
Cladopora sp	c	Pentagonia unisulcata ?	r
Chonetes sp	c	Tentaculites bellulus	c

The Oriskany and Helderberg formations are not exposed at the Stroudsburg cut, but are well exposed, together with a portion of the Esopus, along the Delaware, Lackawanna & Western Railroad near the paper mill 2 miles east of Stroudsburg. Exposures of the Onondaga limestone in the vicinity of the crossroads one-third mile north of the paper mill give a nearly complete section from near the base of the Helderberg limestone to the top of the Onondaga limestone. Below the paper mill the entire thickness of the Oriskany sandstone is seen in the railroad cut, where it stands vertical, forming the backbone of the ridge southeast of Stroudsburg, through which Broadheads Creek breaks. The Oriskany here is only about 50 feet thick. It is followed by dark ash-gray, tough, hard, siliceous shale, about 250 feet thick, which in some beds is slightly calcareous, and which has pronounced slaty cleavage nearly at right angles to the bedding. In lithologic character and stratigraphic position these siliceous beds correspond to the Esopus shale and appear to represent the extension of that formation into northeastern Pennsylvania. The Onondaga limestone, lying above the Esopus, has a thickness of nearly 200 feet. Its appearance indicates that it contains a considerable proportion of argillaceous material. A sample of the limestone from Stroudsburg has been reported[1] by Lesley to show 19.9 per cent of "insoluble residue." So large a percentage of noncalcareous material indicates that contemporaneous beds composed mainly of argillaceous material might be found at no great distance. Some of the Onondaga sections in western New York which show thin bands of shale separating limestone strata of much greater thickness suggest a similar probability. Eight separate thin bands of shale occur within a thickness of 25 feet of the Onondaga limestone at Williamsville, N. Y. As a formation which is chiefly limestone the Onondaga ceases to exist a short distance west of Stroudsburg and is represented by beds which in many places are more argillaceous than calcareous. That the impure limestone seen at Stroudsburg passes into a shale containing subordinate beds of limestone in the region west and southwest of Stroudsburg will be shown in succeeding pages.

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[1] Prosser, Lesley, and White use the older names "Corniferous" and "Cauda-galli" grit instead of Onondaga and Esopus.

West of Stroudsburg the Onondaga limestone outcrops typically about 2 miles west of town, just west of Michaels Creek on the Saylorsburg and Stroudsburg road. Beyond this point, however, lithologically typical exposures cease.

Saylorsburg section.—The area in which the Onondaga limestone should outcrop between Stroudsburg and Saylorsburg is covered by a considerable mantle of drift, but the nearly complete absence of outcrops of the formation in this region indicates that shale probably predominates over the limestone constituent of the formation southwest of Stroudsburg. The first satisfactory exposures of any part of the Devonian section which one encounters in going westward from Stroudsburg occur in the railway cut at Saylorsburg, about 15 miles west of Stroudsburg. The beds there exposed represent only the Oriskany and are indicated in the following section:

Section at Saylorsburg, Pa.

	Feet.
b. Light buffish-brown coarse to medium coarse sandstone, with Oriskany fossils	75
a. Very fine textured cream-colored or buffish tough shale	65

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[1] Summary Rept. Geol. Survey Pennsylvania, vol. 2, 1892, p. 1171.

Neither the beds above nor those below the Oriskany are exposed at Saylorsburg, but 2 miles west of that village the Helderberg limestone has been quarried extensively and is well exposed. Immediately north of these quarries the typical upper Oriskany sandstone and its fossils are seen, and in prospect pits between the Helderberg limestone and the typical Oriskany sandstone the white clay representing the beds *a* of the above section (lower Oriskany) is found. This white shale or clay as it occurs in the ridge immediately east of Saylorsburg is extensively utilized in making a milk-white enamel and brick. So far as known, this phase of the lower Oriskany is without parallel in the Allegheny region, these lower beds, as commonly developed in Pennsylvania, being dark-gray, brownish, or black, more or less calcareous, fine-grained sandstones. Attention is directed to this unusual facies of the lower Oriskany because it occurs in precisely the same area in which a somewhat similar change occurs in the Onondaga formation and because in each area the change consists of a reduction in the calcareous content of the rocks. It is probable that similar physical conditions operated to produce this transformation in the two formations in this area.

White[1] states that the Onondaga is "apparently thin and very arenaceous" in this region. Its failure to outcrop over considerable areas southwest of Stroudsburg indicates clearly its comparatively soft and argillaceous or arenaceous character in that region.

Lehigh River sections.—The Lehigh River section, which is about 5 miles west of Saylorsburg, indicates that the beds representing the Onondaga formation between Stroudsburg and Lehigh River are not only thinner and much less calcareous than the Onondaga to the northeast, but that they are likewise much less calcareous than the same formation to the southwest, in central Pennsylvania.

As with the white lower Oriskany shale and clay at Saylorsburg the unique physical characteristics of the Onondaga formation at Lehigh River has led to its exploitation for commercial purposes, one of the beds which I refer to this formation having been worked for more than 100 years as a paint ore.

So far as observed the beds representing the Onondaga formation do not outcrop on Lehigh River and can be seen only in the drifts of the paint mines but nearly all the rest of the Devonian section is well exposed along the river above Hazard. The following section quoted from Lesley[2] shows the general relation of the beds under consideration in the Lehigh River section:

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[1] Geol. Survey Pennsylvania, vol. G6, 1882, p. 119.

[2] Lesley, J. P., Summary Rept. Geol. Survey Pennsylvania, vol. 2, 1892, p. 1175; Geol. Hand Atlas of Pennsylvania, 1885, p. 33.

Section on Lehigh River above Hazard, Pa.

		Feet.
f.	Gray shales and sandstones (Hamilton)	760
e.	Fissile black shale (Marcellus)	800
d.	Cement layers	30
c.	Shale with iron pyrites	1–2
b.	Drab-colored clay	3–8
a.	Sandstone (Oriskany)	340

Lesley[1] reports that a bed of 5 feet of limestone, which he considered of Onondaga age, lies at the base of the Marcellus shale in one of the paint tunnels near Lehigh River at Hazard, although he has not indicated it in the above section. Bed *c* of the section furnishes the paint ore mined in the vicinity of Hazard and Bowman. The paint ore is carbonate of iron disseminated through a fine-textured shale in which nodules of iron pyrites also occur.

The "cement beds," *d*, above the ore, are shales sufficiently calcareous to be used for cement, thus approaching limestone rather closely in composition. Near Hazard the black shales above the cement beds of the paint mine contain *Ambocœlia umbonata*, *Leiorhynchus limitare*, *Strophalosia truncata*, *Bactrites aciculum*, and *Styliolina fissurella*, indicating a Marcellus horizon.

The beds *b*, *c*, and *d* of the above section are believed to represent the Onondaga formation. Owing to their depth and inaccessibility except in the paint mines no fossils were secured from them and their reference to the Onondaga formation is based on their stratigraphic position between beds containing a Marcellus fauna and the Oriskany sandstone. Their position in the section is identical with that of beds which, in other Pennsylvania and New York sections, are known to carry an Onondaga fauna. Above and below the horizon of the "paint and cement beds" the Devonian section corresponds closely with that of New York in both lithologic and faunal features.

Schuylkill River section.—In the Schuylkill River section, 25 miles southwest of Lehigh River, the fossils afford undeniable evidence of the presence of the Onondaga fauna. About 35 feet of dark bluish-gray argillaceous limestone and interbedded calcareous shale outcrop in the wagon road on the south side of the river at Schuylkill Haven (station 27*c*). The following fauna occur in these beds:

Zaphrentis sp	c	Chonetes mucronatus	a
Fenestella (Polypora) cf. distans	r	C. hemisphericus	a
F. sp	c	Anoplia nucleata	r
Polypora cf. hexagonalis	r	Ambocœlia umbonata	r
Stictopora gilberti	c	Camarotœchia sp	r
Coscinium cf. striaturum	c	Stropheodonta perplana	c
Productella navicella	r	Atrypa reticularis	a

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[1] Summary Rept. Geol. Survey Pennsylvania, vol. 2, 1892, p. 1175.

Leptæna rhomboidalis	c
Schuchertella cf. perversa	r
Pentagonia unisulcata	r
Spirifer acuminatus	r
S. sp. cf. varicosus	c
Schizodus sp	r
Actinopteria sp	r
Platyceras sp	r
Bellerophon leda	r
Tentaculites cf. bellulus	r
Phacops cristata	r

The above association of species can be referred to no other horizon than that of the Onondaga formation, for, although characteristic Onondaga species, such as *Spirifer acuminatus* and *Pentagonia unisulcata*, have in a few places been recorded from a post-Onondaga horizon, others here present, such as *Phacops cristata* and *Anoplia nucleata*, though known at an earlier horizon, are unknown at any later one. The portion of the section immediately below the Onondaga is not exposed in this section, hence no data were obtained relative to the presence or absence of the Esopus.

The Oriskany sandstone is probably in few places more than 5 feet thick in the vicinity of Schuylkill River. No outcrops of it were observed, but its presence is shown by a narrow belt of coarse sandstone or conglomerate bowlders extending across the fields.

West of Schuylkill Haven, on the east side of Schuylkill River, near the Pennsylvania Railroad station, beds outcrop which seem to be the stratigraphic equivalents of the limestone with the Onondaga fauna. They comprise about 20 feet of blocky dark-bluish shales, weathering drab, with thin bands of hard dark-blue impure limestone containing trilobite fragments. A nearly complete section is exposed above these along the railroad up to and through the shales and sandstones of the Hamilton formation. In this section the Marcellus consists largely of clay shales, whose drab color is probably due in part to weathering. The lower part of these shales contain *Leiorhynchus limitare* and *Styliolina fissurella.*

Swatara Creek section.—The valley of Swatara Creek breaks across the Allegheny ridges 15 miles southwest of Schuylkill Haven, affording a good section across a portion of the Devonian rocks at Pine Grove. Along the wagon road about a mile south of Pine Grove the black Marcellus shale is exposed poorly below the Hamilton, which is here a massive, coarse-grained sandstone nearly 200 feet thick. The Onondaga is represented by no satisfactory outcrops, but loose pieces of black thin-bedded and very impure limestone are not uncommon at this horizon. These contain *Anoplotheca acutiplicata, Chonetes mucronatus*, etc.

Falling Spring section.—On the west side of Susquehanna River, in Perry County, the Onondaga may be seen at many localities at the base of the Marcellus shale. When found at drainage level or in the bed of a stream, it is a very hard, tough, argillaceous limestone, generally interbedded with dark or drab shales. If above drainage, the lime is often almost if not completely leached out, leaving a tough, blocky, shalelike rock. In its unaltered condition it is seen at Falling Spring on Shermandale Creek, as shown in the following section:

Section at Falling Spring (station 20).

	Feet.
c. Hard blue argillaceous limestone in layers 8 to 12 inches thick, interbedded with thinner layers of black shale	25
b. Drab, hard, gritty shale, closely mottled with gray wavy lines resembling worm trails	40
a. Hard coarse gray to buff sandstone (Oriskany)	150±

In the limestone beds, *c*, the following fauna occurs:

Strophalosia truncata	a	Cranæna cf. romingeri	r
Chonetes sp	r	Odontocephalus selenurus	c

No fossils were found in the 40 feet of drab mottled shale, *b*, immediately above the Oriskany, and in this respect it corresponds with the Esopus shale, much of which is barren. In physical features its resemblance to the Esopus of southeastern New York is marked. Like the Esopus shale, it occupies the interval between the Oriskany sandstone and the limestone beds containing an Onondaga fauna, thus suggesting its possible equivalence to the Esopus shale.

New Bloomfield sections.—Although Claypole failed to recognize the Onondaga fauna in Perry County, he described [1] a section near New Bloomfield, in which he believed the Schoharie grit to be represented, basing his opinion on the discovery of *Atrypa impressa,* which he considered to represent the same type of the species seen in the Schoharie of New York. Although none of the sections studied by me seem to show conclusive evidence of the presence of the Schoharie grit in Pennsylvania, it may be represented by a portion of the shale of division *b* in the Falling Spring section.

The most satisfactory exposure of the Onondaga which I have seen in Perry County occurs in the following section,[2] at the southwest side of New Bloomfield, just above Clousers Dam. The Marcellus shale, which occupies the valley immediately south of the limestone outcrops, is not exposed in that vicinity.

Section at southwest side of New Bloomfield, above Clousers Dam (station 39).

	Feet.
b. Hard bluish-gray argillaceous limestone and interbedded dark-gray calcareous shale	56
a. Coarse crumbling sandstone (Oriskany)	20

The beds of this section belong to a partly overturned fold, and show a northerly dip of 40° instead of the southerly dip which as part of the south limb of a normal anticline they would exhibit. The limestone and calcareous shale (*b*) of the Onondaga outcrop for about 200 yards above the dam. A partial list of the fossils occurring here follows:

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[1] On the equivalent of the Schoharie grit of New York in middle Pennsylvania: Proc. Am. Philos. Soc., vol. 20, 1883, pp. 534–536.

[2] My attention was first directed to this section by Mr. Luke Baker, of New Bloomfield, to whose zeal the Survey is indebted for a valuable collection of Onondaga fossils.

Zaphrentis cf. simplex	c	Dalmanella lenticularis	c
Orbiculoidea sp	r	Rhipidomella vanuxemi	r
Atrypa reticularis	c	Cyrtina hamiltonensis	r
Ambocœlia umbonata	r	Phacops cf. cristata	r
Anoplia nucleata	r	Bollia ungula	a

Imperfect exposures of leached beds of the argillaceous Onondaga limestone occur one-eighth mile southeast of New Bloomfield, at the Pulpit Rocks. The vertical beds of the Oriskany sandstone, which resist erosion more effectively than the adjacent formations, here form a hill crest of massive sandstone blocks. Immediately south of these (station 39*a*) the olive-gray blocky shale furnished the following species:

Leptostrophia perplana	r	Styliolina fissurella	a
Stropheodonta cf. inequistriata	r	Phacops cristata var. pipa	c
Rhipidomella vanuxemi	a	Acidaspis callicera	c
Dalmanella lenticularis	c	Odontocephalus sp	r
Anoplea nucleata	r	Bollia ungula	c
Nucleospira concinna	c	Bythocypris favulosa	c
Leptænisca australis n. sp	c		

Alinda section.—About 8 miles west of New Bloomfield and three-fourths mile east of Alinda, opposite the Benjamin Zimmer farm, the Onondaga is well exposed in a roadside cutting. The beds include the Devonian section from near the top of the Onondaga nearly to the base of the Helderberg limestone.

Section three-fourths of a mile east of Alinda, Perry County, Pa.

		Feet.
a.	Drab-gray clay shale, ostracodes abundant	15
b.	Hard blue-gray calcareous shale or very argillaceous limestone, trilobites abundant	10
c.	Drab shale with some limy bands	15
d.	Coarse conglomeratic sandstone (Oriskany)	20±
e.	Soft buff sandstone, and covered	80±
f.	Drab shaly blue limestone, with interbedded chert at top	100±

Bed *b* of this section has, as a result of the industry and enthusiasm of Mr. J. W. Shiveley, of Alinda, yielded some of the most complete specimens of trilobites found in the Onondaga (Pls. X–XI).

Iron-ore beds.—In many Perry County sections a band of iron ore 2 feet or less in thickness separates the Oriskany sandstone from the Onondaga shale, though it can seldom be seen except in old ore pits. One of the localities where it is present is 2¼ miles southwest of New Bloomfield, on the Samuel Baker property, 180 yards south of the wagon road, where the old ore drift follows the top of the Oriskany, but neither the ore nor the shales immediately above it are now exposed. At the time when Claypole's survey of the county was in progress some of the ore pits were in operation, showing the thickness and relations of the two iron-ore beds in the Onondaga shale more clearly than they can be seen at present. Claypole[1] gives the following generalized section of these beds:

Generalized section showing iron-ore beds.

	Feet.
Black shale	100
Upper iron ore	2
Limestone [Onondaga]	50
Lime shales [Onondaga]	50
Lower iron ore	2
Oriskany sandstone.	
	204

Selinsgrove section.—Near the forks of Susquehanna River, in central Pennsylvania, the Onondaga fauna occurs in dark bluish-gray argillaceous limestone, which is well exposed just below the Selinsgrove Junction bridge along the Northern Central Railroad. This bed, which is here about 70 feet thick, has been called the Selinsgrove lower limestone by White,[2] who applied the name Selinsgrove shale to the light-gray shale below the limy beds. This shale, which seems to be barren, has a thickness of about 140 feet and appears to hold the same stratigraphic position as the Esopus. No complete list of the fauna occurring in the Selinsgrove limestone of White has been prepared. It includes, however, among others, *Anoplotheca acutiplicata*, *Chonetes* cf. *hemisphericus*, *Ambocœlia umbonata*, *Orthoceras* sp., *Loxonema* sp., *Octonaria stigmata*, and other ostracodes.

McVeytown section.—At McVeytown, 35 miles west of Susquehanna River, the Onondaga fauna is represented in the following section:

Section at McVeytown (station 33).

	Feet.
e. Hard dark-gray to black limestone, in 6 to 12 inch strata, which are somewhat argillaceous at the top	15
d. Covered, mostly shale	20
c. Greenish-gray shale, with three bands of limestone having an average thickness of about 6 inches	10
b. Covered	40±
a. Light-buff to white, fine-grained quartz sandstone (Oriskany)	50±

Fossils were collected from beds *c* and *e* of the above section. The limestone bands, *c* (station 33), afforded the following species:

Chonetes sp	c	Nucula cf. corbuliformis	r
Ambocoelia cf. nana	r	Loxonema sp	r
A. umbonata	c	Styliolina fissurella	a
Stropholosia cf. truncata	r	Dalmanites sp	r
Rhipidomella vanuxemi	c	Bollia ungula	c
Dalmanella lenticularis	c	Ulrichia conradi	r
Nuculites modulatus n. sp	r		

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[1] Second Geol. Survey Pennsylvania, Rept. F2, 1885, p. 64.

[2] Idem, Rept. G7, 1883, p. 360.

In the limestone, *e*, at the top of the section occurs the following fauna:

Orbiculoidea lodiensis var. media	r	Martinia? sp	c
Chonetes mucronatus	r	Odontocephalus selenurus	c
Stropholosia truncata	c		

Upper Reese section.—The most westerly outcrops of the Middle and Lower Devonian rocks in Pennsylvania are found in the belts of inclined strata which dip under the Allegheny front and trend southward or southwestward to the Maryland line from the vicinity of Hollidaysburg. Sections in this region which expose the Oriskany sandstone and the beds immediately following are very similar to those previously described from the more easterly sections. The following is a representative section taken at side of the highway a few miles east of Hollidaysburg and 1½ miles south of Upper Reese station.

Section 1½ miles south of Upper Reese station (station 31).

		Ft.	in.
a.	Fissile black clay shale (Marcellus)	30+	
b.	Covered	60±	
c.	Greenish thinly laminated shale, somewhat calcareous	6	
d.	Gray, nearly pure limestone	1	
e.	Green shale, like *c*	2	
f.	Dark, rather earthy limestone		10
g.	Green shale, like *c*, with very calcareous bands	18	
h.	Dark-gray limestone	1	
i.	Greenish clay shale	2	
*j*1.	Fissile black clay shale, containing *Chonetes mucronatus* and *Stropholosia*	22	
*j*2.	Fissile black shale, as above, with *Orbiculoidea* and *Conularia*	10	
k.	Covered, but shale weathering to light-colored clay	10	
l.	Red iron-ore band		6±
m.	Buff crumbling sandstone (Oriskany)	20+	

The faunal details are shown by the following lists of species collected from the several divisions of the section. Fossils are present in the lower beds, but the black shales *j*1 and *j*2 are the lowest beds that show an abundance of individuals, though few species.

Station 31, *j*1:	
Stropholosia truncata	a
Chonetes cf. mucronatus	a
Station 31, *j*2:	
Orbiculoidea lodiensis var. media	a
Bactrites cf. aciculum	c
Conularia sp	c

In the greenish clay shales, *i*, next above, the following species occur:

Styliolina fissurella	a
Bythocypris favulosa	a

The beds that are richest in fossils in this, as in most other sections showing this fauna, are the calcareous beds. These are typically developed in *g* of the section, which furnished the following species:

Ambocœlia umbonata	c
Anoplia nucleata	r
Pholidops cf. areolata	r
Modiomorpha sp	r
Styliolina fissurella	a
Bactrites? sp	r
Dalmanites (Cryphæus) cf. boothi var. calliteles	r
Odontocephalus cf. cristata	r
Bollia ungula	c
B. obesa	c

The fossils from the other calcareous bands (*c–h*) of the upper part of the section are not separately listed but are included together in the following list:

Productella sp	r
Chonetes buttsi n. sp	r
Ambocœlia umbonata	c
Atrypa reticularis	a
Anoplotheca acutiplicata	c
A. cf. camilla	r
Odontocephalus ægeria	c
Leperditia? cf. subrotunda	r

Hollidaysburg section.—The stratigraphic relations of the Onondaga fauna to the Oriskany and Helderberg formations are well shown just east of Hollidaysburg along the highway and railroad on the east side of Brush Run. The section exposed here begins in the Helderberg limestone and includes the Onondaga. It is as follows:

Hollidaysburg section (*station 28*).

		Feet.
m.	Fissile black clay shale	20+
l.	Greenish-buff blocky clay shale, with *Loxonema*, *Anoplotheca*, etc. (Onondaga)	10
k.	Fine-grained buff crumbling sandstone, mostly disintegrated to sand (Oriskany)	55±
j.	Rather fine-grained buff, loosely cemented sandstone, with numerous typical Oriskany fossils	28
i.	Dark lead-gray, very fine grained calcareous sandstone, with Oriskany fossils (large *Lingula*, etc.)	3
h.	Buff or drab, very fine textured thin-bedded rock of extremely light weight and highly porous texture in strata 2 to 10 feet thick. Originally a highly calcareous limestone from which the lime has been wholly leached. Trilobites, *Chonetes*, *Conularia*, etc	35
g.	Dark-gray, somewhat calcareous but very siliceous shale	160
f.	Bluish-gray limestone and some interbedded dark shale	15
e.	Blue-gray, rather coarse limestone at top, finer at base; chert balls in upper portion; fossils common	20
d.	Shaly gray limestone	10
c.	Drab or gray earthy argillaceous limestone, with numerous distinctly shaly bands; the whole fossiliferous	65
b.	Blue-gray, somewhat impure limestone, but with some bands of crystalline limestone not seen in preceding; very fossiliferous	25
a.	Dove-gray fine-grained limestone of sublithographic texture, in thin strata mostly 1 to 3 feet thick; very few fossils	80

With the exception of ostracodes, fossils are scarce in the Onondaga fauna at this point. From *l* (station 28) the following species were secured:

Orbiculoidea lodiensis var. media	a
Anoplotheca acutiplicata	r
Loxonema cf. pexata	r
Bactrites aciculum	r
Bollia ungula	c
Leperditia? cf. subrotunda	r

Canoe Creek section.—The richest locality for the Onondaga fauna which was visited in Blair County was discovered by Charles Butts 2 miles west of Canoe Creek at the side of the wagon road. The exposures here show the following beds:

Section 2 miles west of Canoe Creek, Blair County, Pa. (*station 32*).

	Ft.	In.
d. Greenish-gray or drab argillaceous limestone, with trilobites, *Atrypa reticularis*, *Anoplotheca*, etc		10–15
c. Yellow, green, and black clay shale, light colored at top; numerous fossils	20	
*b*1. Calcareous shale, with trilobites	6	
b. Drab or greenish papery shale with *Chonetes mucronatus*, etc	12	
a. Buff sandstone and concealed (Oriskany)	8	

From the limestone band, *d* of the section, the following fauna was collected:

Zaphrentis sp	c
Ambocœlia cf. umbonata	c
Chonetes buttsi n. sp	c
C. sp	r
Atrypa reticularis	c
Anoplotheca cf. camilla	r
A. acutiplicata	c
Stropheodonta inequistriata	r
Schuchertella cf. perversa	c
Pleurotomaria crassa n. sp	r
Styliolina fissurella	a
Dalmanites (Coronura) aspectans?	r
Phacops cristata var. pipa	c

The fauna from the remainder of the beds, which were not separately marked on the collections, are shown in the following list:

Lingula cf. ligea	a
Orbiculoidea sp	
Pholidops cf. areolata	c
Strophalosia truncata	c
Chonetes mucronatus	a
C. buttsi n. sp	c
C. cf. setigerus	c
Ambocœlia umbonata	r
Schuchertella cf. perversa	r
Anoplotheca acutiplicata	c
Palæoneilo cf. constricta	r
Panenka cf. multiradiata	c
Nucula sp	r
Loxonema cf. pexata	r
Naticopsis sp	r
Platyceras sp	
Bellerophon cf. pelops	c
B. sp. undet	r
Coleolus curvatus n. sp	c
Tentaculites sp	r
Hyolithes cf. aclis	r
H. cf. principalis	r
Styliolina fissurella	a
Orthoceras cf. subulatum	c
Octonaria stigmata	r
Bollia obesa	r

MARYLAND.

General relations.—In Maryland the stratigraphic relations of the Onondaga shale do not differ greatly from those seen in Pennsylvania. In general the impure limestone which in Pennsylvania lies at the base of the Marcellus is somewhat less important in Maryland, being in many places almost, if not entirely, supplanted by the dark and drab shales. The sections embracing the Onondaga include at the base the coarse buff-brownish or white Oriskany sandstone, which in most places is about 250 feet thick, though sometimes differing widely from this, and which is followed above by drab or dark-colored shale holding the Onondaga fauna and some thin bands of impure limestone. The shales in which drab or light colors predominate are followed by others that are chiefly of the black fissile type representing the Marcellus and that contain few fossils besides *Leiorhynchus limitare* and *Styliolina fissurella.* This Marcellus shale is overlain by shale and sandstone with typical Hamilton fossils.

The above-noted shales and sandstones, although embracing three distinguishable types of sediments and three very unlike faunas, have been classed together under the name Romney shale by the geologists of the Maryland Survey. Prosser[1] recognized the facts that the upper arenaceous shales and sandstones contained a characteristic Hamilton fauna and that the fissile black shales just below them represented the Marcellus of the New York section. The whole of the shale series, amounting to a thickness of about 1,600 feet, includes not only a Hamilton and a Marcellus fauna, but an Onondaga fauna as well at the base of the Marcellus, the three having the same relative stratigraphic limits as in the New York section. The general relations of these three members of the Romney are well shown in the three railway cuts at Twenty-first Bridge, in western Maryland. In the northern part of the Baltimore & Ohio Railroad cut at this locality the Hamilton fauna occurs abundantly. The Marcellus shale immediately below is nearly barren, except for *Leiorhynchus limitare,* which is abundant in the lower beds exposed at the south end of the same cut. Two cuts of the Western Maryland Railroad at Twenty-first Bridge expose the Onondaga shale, about 100 feet thick, lying below the Marcellus, showing the 8 or 10 feet of limestones with *Goniatites* at its top and a part of the Oriskany at its base. At this locality fossils are scarce in the Onondaga, but *Anoplotheca acutiplicata* is the abundant and dominant fossil at the second cut west of Twenty-first Bridge, as it is at most other localities in the Onondaga shale.

Hancock section.—The Onondaga fauna has been observed at several localities along the Potomac, in outcrops east of Cumberland,

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[1] Prosser, C. S., Jour. Geology, vol. 9, 1901, p. 419.

and at Tonoloway and Hancock. The Onondaga fauna was found in green blocky clay shale on the hill northwest of Hancock, just east of the old sand quarry. About 60 feet above the Oriskany sandstone at this locality (station 41*c*, Hancock, Md.) the following fossils were secured:

Ambocœlia umbonata	r
Styliolina fissurella	a
Phacops sp. undet	r

Typical thin, papery black shales of Marcellus type are exposed in the shale quarry about 50 feet above this fauna. The Marcellus here, as in most of the Allegheny sections, is largely concealed in the slopes of a valley excavated in the easily eroded beds of the Marcellus, which appear to have a thickness of not more than 400 feet at Hancock.

Tonoloway section.—The section at Tonoloway, opposite Great Cacapon, exposes nearly the whole of the Devonian below the Catskill, the only exception being the Marcellus, which is almost entirely concealed in the bottom of a small valley that reaches the Potomac along the strike of the beds of this portion of the section. At the base of the Marcellus, immediately above the Oriskany sandstone, about 60 feet of interbedded greenish-drab and black blocky shale representing the Onondaga is exposed. The following fauna was found in these beds (station 52*h*, Tonoloway, Md.):

Strophalosia truncata	c	Styliolina fissurella	a
Rhipidomella vanuxemi	c	Phacops cristata	r
Ambocœlia umbonata	c	Bollia ungula	c
Nucleospira concinna	c	B. obesa	r
Dalmanella lenticularis	c	Craterellina [1] n. g	r
Anoplia cf. nucleata	r	Polygnathus sp. undet	r
Leptænisca australis n. sp	r		

About 400 feet or more above the beds containing this fauna beds containing the typical Hamilton fauna appear in this section.

Cumberland section.—A section along the Williams road 3½ miles east of Cumberland, which shows a nearly continuous exposure of the beds from the Oriskany sandstone to the horizon of the Hamilton fauna, affords a clear conception of the essential characteristics of the different divisions of the Romney. Owing, however, to the presence of some minor folding and buckling of beds in the lower part of the section, to which Dr. Charles K. Swartz called the writer's attention, the precise thickness of some of the beds following the Oriskany sandstone can not be given. It appears that from this cause some of the beds of the Onondaga are duplicated, thus giving this member of the Romney a greater apparent thickness in this section than usual. Several successive faunules were collected from this section and their order of succession, beginning with a faunule from beds directly above the Oriskany sandstone, is indicated by the letters attached to them. The lowest division of the shales contains a profusion of individuals but a very small number of species, as indicated by the following list:

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[1] Manuscript, Ulrich, E. O., and Bassler, R. S.

Station 45b, east of Cumberland, Md.

Lead-gray to black nonfissile shale 55 feet thick immediately above the Oriskany furnished the following species:

Orbiculoidea lodiensis var. media	a	Bactrites aciculum	c
Anoplotheca acutiplicata	a	Enchostoma ? sp.	

A much more varied fauna occurs in the next division of the section, where the following species were found in part of division *c* in argillaceous green and drab shales lying above the beds last named:

Station 45c, east of Cumberland, Md.

Chonetes mucronatus	a	Grammysia sp	r
Chonetes rugosus n. sp	c	Euthydesma?	r
Pholidostrophia pennsylvanica n. sp	r	Modiomorpha subalata	r
Anoplotheca acutiplicata	r	Naticopsis sp	c
Anoplotheca camilla	r	Loxonema hamiltoniæ	r
Ambocœlia umbonata	a	Euomphalus sp	r
Nucleospira cf. concinna	r	Goniatites sp	r
Reticularia cf. fimbriata	r	Bactrites aciculum	c
Nuculites modulatus n. sp	r	Bollia ungula	c
Palæoneilo cf. constricta	r	Bollia obesa	r
Leiopteria lævis	r		

Although some species in this fauna, like *Nuculites modulatus*, are closely allied to or identical with Hamilton species, the presence of such species as *Anoplotheca acutiplicata* and *Anoplotheca camilla*, which have always been considered Onondaga or pre-Onondaga species, requires the assignment of this bed to the Onondaga horizon.

Still higher, in division *d*, we find the following species:

Station 45d, Cumberland, Md.

Pholidops cf. areolata	r
Anoplotheca acutiplicata	c
Agoniatites cf. expansus	r

This appears to be the highest fauna which shows definite affinities with the Onondaga.

In *g* we find a Marcellus fauna, which is represented by the following congeries:

Station 45g, Cumberland, Md.

Strophalosia truncata	c	Leiorhynchus cf. nysius	a
Leiorhynchus limitare	c	Buchiola retrostriata	r

In this as in many other sections no very sharp line can be drawn between the sediments holding the Onondaga and the Marcellus faunas, the one grading into the other. Taken as a whole, however, the upper or Marcellus shales are decidedly blacker and comparatively freer from light-colored shales than is the lower series, in which green and drab-colored shales predominate.

The *Tropidoleptus carinatus* fauna was found in a bed of gray sandstone which lies not far above the base of the Hamilton member.

WEST VIRGINIA.

General conditions.—The belts of Lower Devonian rocks which cross Maryland in conformity with the Allegheny structure continue southward across the Potomac through northeastern West Virginia, with a south-southwesterly trend. The two belts of Devonian rocks on opposite sides of the New Creek Mountain anticline in Mineral County are the most westerly of the Lower Devonian rocks which reach the surface in West Virginia. Collections representing the Onondaga fauna were made from both of these belts, one at Rees Tannery, at the foot of the Allegheny Front, and the other at Ridgeville. Another section, including these rocks, was studied farther east, at Berkeley Springs.

The coarse Oriskany sandstone everywhere lies at the base of the Devonian shale series in West Virginia, as it does in Maryland and Pennsylvania. The Oriskany is well exposed in the vicinity of Keyser, where the New Creek Mountain uplift is cut through by the Potomac. Nearly opposite the station at Keyser the Oriskany rises above the Potomac and, arching up in New Creek Mountain almost vertically 400 feet above the river, forms the bold cliff at Queens Point opposite Keyser. South of the Potomac the east and west slopes of the New Creek Mountain ridge are each flanked by a belt of the Oriskany sandstone. Immediately above this formation in the section is the shale series called the Romney shale in the United States Geological Survey folios[1] that describe this region and the Hamilton shales by the West Virginia State Survey.[2] Neither of these terms is entirely satisfactory. The use of the term Hamilton involves the correlation of beds of Onondaga, Marcellus, Hamilton, and Portage age with the Hamilton formation of New York, which is manifestly indefensible. The use of the term Romney avoids questions of correlation, and in the ordinary formational sense, with various members, it is convenient and useful (p. 18). As used in this bulletin the name Onondaga shale member is applied to the lowest lithologic division of the Romney, including the calcareous bands and lighter-colored shales near the base of the Romney.

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[1] Folios 28, 32, Geol. Atlas U. S., U. S. Geol. Survey, 1896.

[2] Grimsley, G. P., Iron ores, salt, and sandstones: West Virginia Geol. Survey, vol. 4, 1909, pp. 156, 188.

Ridgeville section.—The territory between Ridgeville and Berkeley Springs includes the type area of the Romney shale. Three distinct and successive faunas—Onondaga, Marcellus, and Hamilton—are included in the rocks assigned to this formation by Darton.[1] The three types are limited, respectively, to three types of sediments which comprise the Romney. The lowest of these includes mainly alternating drab or green and black clay shales with a few thin bands of impure limestones. Following these are a series of generally fissile black shales with comparatively few drab or light-colored shales. The uppermost division includes drab sandy shales and sandstones with the Hamilton fauna. These two upper divisions in the more easterly sections are sharply differentiated lithologically, as at Hedgesville and Hancock. The different faunal and lithologic elements of the Romney shale are shown in the Ridgeville section, which is exposed on the east slope of New Creek Mountain along the wagon road near Ridgeville post office. It is as follows:

Ridgeville section, on east slope of New Creek Mountain, near Ridgeville, W. Va. (*station 51*).

		Feet.
e.	Drab sandy shale, becoming softer upward	300±
d.	Black to lead-gray carbonaceous fissile clay shale	250±
c.	Greenish-drab shale and impure limestone as below, fossils common	50±
b.	Black and greenish interbedded clay shale, with bands of greenish earthy and very impure limestone near top; fossils abundant	75±
a.	Brownish-buff sandstone with Oriskany fossils (Oriskany sandstone)	75±

It will be noted that in the lower 150 feet of this section above the Oriskany light-colored beds predominate, whereas in the next 250 feet they are nearly or entirely absent. The lower 75 feet of shale, *b*, is characterized by the following fauna, indicating its Onondaga age:

Orbiculoidea lodiensis var. media	c	Nucula cf. corbuliformis	r
Lingula cf. ligea	r	Cypricardinia sp	r
Craniella hamiltoniæ	c	Lunulicardium curtum	r
Pholidops cf. areolata	c	Actinopteria muricata	c
Strophalosia truncata	c	Platyceras sp	r
Chonetes sp	c	Naticopsis sp	r
Dalmanella lenticularis	r	Loxonema hamiltoniæ	c
Ambocœlia umbonata	r	Orthoceras sp. (small sp.)	r
Anoplotheca acutiplicata	a	Bactrites aciculum ?	r
Cranæna cf. romingeri	r	Hyolithes cf. aclis	r
Pholidostrophia pennsylvanica n. sp	r	Phacops cristata	r
Rhipidomella vanuxemi	r	Conolichas hispidus ?	r
Nuculites modulatus n. sp	r	Cryphæus cf. boothi var. calliteles	c
Panenka cf. dichotoma	r	Bollia obesa	c
Aviculopecten equilatera	r		

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[1] Darton, N. H., Am. Geologist, vol. 10, 1892, p. 17.

In *c* of the section the fauna is similar to that of *b*, but less abundant. In the next division, *d*, the fauna is very meager. Unlike the preceding fauna, it includes no characteristic Onondaga species. In the lower part of *d* (*d*1) the following species, one of which may be regarded as a characteristic Marcellus fossil, are found:

Station 51*d*1:

Strophalosia truncata	r
Leiorhynchus limitare	c

In the upper part, *d*2, occurs the following faunule:

Station 51*d*2:

Chonetes cf. scitulus	r
Leiorhynchus limitare	c
Buchiola sp	r

Both of these faunules are regarded as representing the Marcellus fauna. The beds containing them are overlain by a drab sandy shale, *e*, containing a very different fauna, in which the two most common species are *Chonetes setigerus* and *Tropidoleptus carinatus*. The presence of *Tropidoleptus carinatus* plainly indicates the Hamilton. The Hamilton fauna here appears to be rather meager, but farther east, at Hedgesville, the sandstones and shales of the Hamilton afford a fauna which in the number of species represented is as rich as at the average locality in central New York.

Rees Tannery section.—At Rees Tannery, station 50*a*, about 2½ miles west of the section just given, the lower part of the Romney afforded the following fauna, representing the Onondaga:

Zaphrentis sp	r
Orbiculoidea lodiensis var. media	c
Ambocœlia cf. nana	r
Dalmanella lenticularis	r
Anoplia nucleata	r
Anoplotheca acutiplicata	c
Nucleospira concinna	r
Styliolina fissurella	a
Dalmanites sp. undet	r
Phacops cristata	c
Bollia ungula	c

Berkeley Springs section.—About 1¾ miles south of Berkeley Springs, W. Va., the wagon road cuttings expose the Oriskany sandstone and the lower portion of the Romney including most of the shales holding the Onondaga fauna. The following section was noted here:

Section 1¾ miles south of Berkeley Springs (*station 43*).

		Feet.
f.	Fissile black shale, and covered	250
e.	Covered	35
d.	Black blocky argillaceous shale, full of fossils	20
c.	Drab shale, weathering cherry-red in places; fossils scarce	18
b.	Cream or light putty-colored clay and shale, with some buffish layers	10
a.	Buffish-brown sandstone, crumbling to sand (Oriskany)	60+

The lowest fossils observed in the shales of this section occur in *c;* they are *Craniella hamiltoniæ, Leptostrophia perplana,* and *Ambocœlia umbonata.*

In *d* occurs the following fauna:

Chonetes sp	r	Nucula cf. corbuliformis	r
Ambocœlia umbonata	a	Cypricardinia ? sp	r
Nucleospira concinna	c	Styliolina fissurella	a
Anoplia nucleata	c	Phacops cristata	c
Dalmanella lenticularis	a	Cyphaspis cf. stephanophora	r
Leptænisca australis n. sp	c	Leperditia ? cf. subrotunda	r
Pholidostrophia pennsylvanica n. sp	r		

The Marcellus in the section is imperfectly exposed and no fossils were observed in it.

Romney.—At the type locality of the Romney shale, Romney, W. Va., two faunas—the Onondaga and the Hamilton—are found. The meager Marcellus fauna is doubtless also present, though not observed. These faunas occur, respectively, in the lower and upper parts of the Romney. In the vicinity of Romney the Onondaga shale member may be seen along the road through Mill Creek Mountain Gap, 1½ miles southwest of town. Here the section shows an abrupt transition from the gray, highly calcareous coarse sandstone full of Oriskany fossils to drab shale, approximately 100 feet thick, with some calcareous bands containing the Onondaga fauna. Fossils are not so readily found as at many other localities. Among those collected are *Anoplotheca acutiplicata, Dalmanella lenticularis,* and *Ambocœlia umbonata.*

The black shale representing the Marcellus is well exposed on the opposite side of the south branch of Potomac River and appears to be barren. A little higher up the hill to the eastward on the west side of Romney the black fissile shale is succeeded by olive to gray slightly sandy shale with Hamilton fossils, which may be collected near the railroad station at Romney.

Moorefield.—The Onondaga fauna occurs abundantly and in a good state of preservation 2 miles west of Moorefield along the road to Maysville. The stratigraphic relations of the beds here, however, are not clearly defined and the outcrops do not afford a very satisfactory section. At Maysville the Onondaga, together with the beds above and below it, is well exposed at the eastern end of Cosner Gap through New Creek Mountain. At this locality, as at many others, *Anoplotheca acutiplicata* is the most conspicuous fossil.

Fort Seybert.—The Onondaga doubtless occurs as far south in West Virginia as White Sulphur Springs, but Fort Seybert, in Pendleton County, is the most southerly point in this State at which the Onondaga fauna was collected. About one-half mile south of Fort Seybert the drab and dark shale of the Onondaga outcrops at the side of the Brandywine road. The fauna found at this point includes among other species *Dalmanella lenticularis*, *Anoplotheca acutiplicata*, *Phacops cristata*, and *Bollia ungula*. A typical Hamilton fauna, represented by a great abundance of fossils, occurs near this locality.

VIRGINIA.

General relations.—The shales in Virginia which contain an Onondaga fauna, except those in the extreme southwestern part of the State, have been included with the shales of Marcellus and Hamilton age under the name Romney shale in the folios of the United States Geological Survey. In the Bristol folio the term Romney is not used, and a considerable portion (at least 500 to 800 feet) of the beds which farther north are called Romney are known as the black Chattanooga shale. In the Staunton quadrangle 600 to 1,000 feet of dark shales are assigned to the Romney. The typical Hamilton fauna, which in Maryland and West Virginia characterizes the upper part of the Romney shale, has in central and southwestern Virginia given place to a facies of very different type from that found farther north. Except in the extreme southwestern part of the State, however, the Onondaga fauna, with which this paper is chiefly concerned, shows no important deviation from the facies seen in West Virginia and Maryland. At Big Stone Gap a distinct facies with a coralline fauna appears. With this exception the Onondaga fauna continues to occupy the basal portion of the Devonian shale series in Virginia as in the more northerly States. In the region of James River it occurs in the lower part of the Romney, and nearer the Tennessee line it lies just at the base of the Chattanooga shale. The components of this fauna and its stratigraphic relations will be shown in the descriptions of some of the representative sections. In the James River region and northward, where the Onondaga shale grades into the next higher division of the Romney, it may conveniently be treated as a member of the Romney shale. In southwestern Virginia, the transition is an abrupt one, the Onondaga limestone being followed by a black shale called the Chattanooga shale. As the Onondaga is here only 5 feet thick—too thin to map—and as it has been included in the Chattanooga shale of this region, it will be treated as a member of the Chattanooga, as to the north it is treated as a member of the Romney shale.

Hayfield.—South and southwest of the sections which have been described in West Virginia the Onondaga shale may be found at the proper horizon along most of the wagon roads which cross the country at right angles to the general strike. The fauna of this shale occurs along the road from Winchester to Capon Bridge and abundantly at Hayfield, where limestone beds comprise an important element in the Onondaga shale member. *Anoplotheca acutiplicata* occurs in them in abundance. A few hundred yards west of Hayfield the Oriskany is seen in the wagon road at the base of the Onondaga.

Shenandoah Alum Springs.—About 45 miles southwest of Hayfield a small collection of the Onondaga fauna was made on the east side of North Mountain at Shenandoah Alum Springs. The fauna occurs here in drab-colored shales, which may be seen at the rear of the old iron-ore furnace. Among the fossils collected are *Phacops cristata*, *Acidaspis callicera*, and *Octonaria* cf. *stigmata*.

The section including the Onondaga is as follows:

Shenandoah Alum Springs section.

	Feet.
Drab ash-colored shale, with Hamilton fossils at base	60±
Fissile black shale, with one or more bands of limonite ore. In lower part occur thin bands of very soft carbonaceous matter, with some large concretions of black limestone; fossils rare	300±
Drab to cream-colored shale, with Onondaga fossils	35±
Gray sandstone, coarse, conglomeratic, with typical Oriskany fossils	50±

Owing to structural complications it is impossible to give more than a rough estimate of the thickness of the Oriskany sandstone and the Marcellus member of the Romney at Shenandoah Alum Springs. The relationship of the Onondaga shale member to these beds, however, is perfectly clear, although its precise thickness was not determined.

Stribling Springs.—About 40 miles southwest of Shenandoah Alum Springs a portion of the Onondaga shale member appears to be partly exposed in the section at Stribling Springs just below the hotel grounds. The Oriskany, and apparently a part of the Onondaga member, is here cut out of the section by faulting.

Bells Valley.—Twenty-five miles southwest of Stribling Springs, along the trend of the structure, the following excellent section of the Lower Devonian rocks is exposed at Bells Valley, between the quarry and the church south of the station.

Section at Bells Valley, Va. (station 57).

		Feet.
l.	Hard thin sandy shale and thin-bedded sandstone, with abundant *Pararca*, etc	100+
k.	Drab to buffish soft clay shale, with Portage fossils	60±
j.	Fissile black shale, with some bands of impure limestone	150±
i.	Drab and dark lead-colored soft shale, with lenses and concretions of dark limestone; *Buchiola speciosa* very abundant	60±
h.	Covered	40±
g.	Fissile black, much crumpled shale	50
f.	Drab and greenish soft clay, with some very thin bands of black shale holding a rich fauna	25
e.	Covered	40±
d.	Drab to greenish blocky shale, with some slightly limy bands	45

	Feet.
c. Soft brownish sandstone, crumbling to sand (Oriskany)	35±
b. Dark-blue limestone, some chert lentils in upper part, and numerous fossils	45±
a. Gray crystalline limestone	50±

The first three divisions of this section above the Oriskany sandstone are referred to the Onondaga shale member of the Romney shale. In the lower shales, *d*, immediately above the Oriskany sandstone the following fauna occurs:

Orbiculoidea lodiensis var. media	c
Strophalosia truncata	c
Nucleospira concinna?	r
Cranæna cf. romingeri	a
Anoplotheca acutiplicata	r
Buchiola sp	r
Bellerophon leda	r
Phacops rana	a
Bollia ungula	
Bythocypris favulosa	

Similar to the above is the following fauna, which occurs in the next exposed division, *f:*

Chonetes mucronatus	r
Leiorhynchus cf. limitare	c
Anoplia nucleata	c
Ambocœlia umbonata	a
Anoplotheca camilla	r
Actinopteria sp	c
Buchiola sp	r
Leptodesma sp	r
Nucula corbuliformis	r
Bellerophon leda	r
Pleurotomaria sp	r
Tentaculites gracilistriatus	c
Styliolina fissurella	c
Bactrites cf. aciculum	r
Bollia obesa	c

The next division, *g*, changes from predominating drab or light-colored shales to black shale, and with this lithologic modification occurs a very marked change in the type of the fauna:

Leiorhynchus limitare	a
Leiorhynchus nysius	c
Nuculites modulatus n. sp	r
Buchiola retrostriata	c
Styliolina fissurella	a
Coleolus tenuicinctum	r

In this fauna *Buchiola retrostriata* and *Leiorhynchus nysius* make their first appearance in the section as common or dominant species. Simultaneous with the appearance of these species in abundance is the disappearance from the section of *Anoplotheca acutiplicata* and *Anoplia nucleata.* The Onondaga fauna may therefore be considered to be limited to the shales *d, e,* and *f.*

In this region the Hamilton fauna has so completely lost the features which distinguish it farther north from the Marcellus that it is hardly practicable to separate the two faunas. The following fauna, *i*, and the one just listed are the representatives of this portion of the Devonian fauna in this section:

Chonetes cf. mucronatus	r
Leiorhynchus limitare	a
Buchiola halli	a
Orthonota? sp	r
Styliolina fissurella	c
Goniatites sp	r

This fauna is followed by a typical Portage fauna of the western New York type. Still higher in the section and preceding the Chemung faunas is found the eastern Portage or Ithaca fauna.

Clifton Forge.—Near Clifton Forge, Va., the Onondaga member is well exposed along the Chesapeake & Ohio Railway, both east and west of town. The following section is exposed along the railroad one-half mile west of the station:

Section west of Clifton Forge, Va. (station 58).

		Feet.
e. Drab and greenish shale		100±
d. Yellow and olive shale and sandstone		20
c. Brownish-gray sandstone, with Oriskany fossils		4–10
b. Gray subcrystalline limestone, with thin chert lentils in lower part	Helderberg	36
a. Black chert and interbedded limestone		54

In this section the angular unconformity between the Oriskany sandstone, *c*, and the Helderberg limestone, *a* and *b*, is well shown at the side of the railroad. The slight thickness of the Oriskany in this section is evidently due to the unconformity, the greater part of it being absent. The Onondaga shale member is represented by the remainder of the section, *d* and *e*.

The following fauna occurs in the lower 20 feet of the shale, *d:*

Zaphrentis cf. simplex	r	Anoplotheca acutiplicata	c
Procteria sp	r	Pleurotomaria cf. trilix	r
Pholidops sp	r	Actinopteria muricata	c
Orbiculoidea lodiensis var. media	r	Styliolina fissurella	a
Ambocœlia umbonata	r	Phacops cf. cristata	r
Strophalosia truncata	r	Bollia ungula	c
Anoplia cf. nucleata	r	Ostracodes undet	a
Dalmanella lenticularis	c		

Three-fourths of a mile east of the Clifton Forge railroad station the railroad cuts expose the following section:

Section east of Clifton Forge, Va. (station 59).

	Feet.
d. Black fissile shale, crushed and crumpled	100±
c. Drab or greenish shale, slightly calcareous and blocky near base	45
b. Brownish coarse sandstone (Oriskany)	12
a. Gray crystalline limestone	5+

The Onondaga fauna is represented in the drab shales, *c*, by the following fauna:

Cladopora sp	r	Dalmanella lenticularis?	c
Zaphrentis sp	r	Anoplotheca acutiplicata	c
Crinoid stems	c	Platyceras sp	r
Orbiculoidea sp	r	Odontocephalus ægeria	r
Anoplia sp	r	Bollia ungula	c
Ambocœlia umbonata	a	Bythocypris favulosa	r

Mountain Grove.—Throughout the James River region the Onondaga shale member is characterized by an Onondaga fauna of the type seen in the preceding lists. *Anoplotheca acutiplicata* is generally present. The most westerly locality in this district in which this fauna was collected is at Mountain Grove, Bath County, near the West Virginia line. In the western part of Bath County the valley of Back Creek is cut for many miles in the soft shales of the lower part of the Romney. On one side of it the Oriskany sandstone and lower beds of more resisting character form Back Creek Mountain. On the other side the hard sandy shales of the Jennings and Hampshire formations have given rise to the long mountain ridge called Little Mountain. At Mountain Grove Little Back Creek has cut directly across these formations and the Romney formation, exposing a good section of the rocks. The generally westerly monoclinal dip along this stream is somewhat complicated by local flexures, which make accurate estimates of the thicknesses of the lower subdivisions of the Romney impracticable. The general succession, however, is clearly indicated and is shown in the following section, in which the thicknesses are for the most part only approximate:

Mountain Grove section (station 61).

	Feet.
g. Thin-bedded hard gray sandstone and interbedded shale	800
f. Rather hard sandy dark-blue shale and some thin bands of sandstone with Portage fauna	700±
e. Black hard fissile shale	100
d. Covered	70
c. Hard black and dark greenish-gray calcareous shale	6
b. Black blocky tough shale	20
a. Dark coarse ferruginous sandstone, with frequent concretions of pyrites (Oriskany)	20+

In the calcareous shale, *c*, near the base of the section the following species were found:

Orbiculoidea lodiensis var. media	a
Anoplotheca acutiplicata	c
Conularia sp	r

No fossils were found in the fissile black shales, *e*, which probably represent the Marcellus and Hamilton. Above these beds in hard sandy shales occurs a typical Portage fauna, and this is followed by the Chemung fauna in *g*.

Catawba Mountain.—About midway between James and New rivers a section was studied on the southeast slope of Catawba Mountain. The Onondaga shale member is exposed along the Red Sulphur Springs and Salem road, 7 miles northwest of Salem, and a short distance above the railroad. A portion of the section follows:

Catawba Mountain section.

		Feet.
c.	Fissile black and drab shale, largely covered	100+
b.	Light ash-colored or drab argillaceous soft shale (Onondaga fossils)	?
a.	Coarse crumbling white sandstone with a few thin bands of purple sandstone; only a few small fragments of fossils seen	200±

The light-colored argillaceous shale, *b*, contains *Zaphrentis* cf. *simplex*, *Cladopora* sp., *Leptænisca australis* n. sp., *Dalmanella lenticularis*, *Anoplotheca acutiplicata*, *Odontocephalus ægeria*, *Bollia ungula*.

Little Walker Creek.—South of New River the Onondaga fauna is still associated with light-colored somewhat calcareous shales at or near the base of the Romney, which, together with shales above and below it, are exposed in the Little Walker Creek gap through Walker Mountain and along the highway east of the gap across Little Walker Mountain, in Bland County, 7½ miles northwest of Dublin, as shown in the following section:

Little Walker Creek section (station 66).

		Feet.
h.	Drab sandstone and interbedded shale of light color, which crumbles readily to small many-sided fragments; typical Chemung fauna	670+
g.	Tough, hard dark-gray siliceous shale merging into *f* at base, with thin sandstone bands above; Portage fossils at base	600±
f.	Black hard fissile shale	250±
e.	Covered and dark shale, calcareous near the base (not seen in the creek section but outcrops at the roadside about one-half mile up the valley, near a spring)	75±
d.	Buff or gray chert (in bed of stream)	10±
c.	Soft coarse gray sandstone (Oriskany?)(in bed of stream)	20
b.	Hard dark-gray calcareous fine-grained sandstone (in bed of stream)	2
a.	Hard gray quartzite	100+

The fauna which in this section is referred to the Onondaga occurs about one-half mile southwest of the gap at a spring by the side of the road to Sassin in a dark shaly limestone or calcareous shale. The species obtained here (station 66*e*) are the following:

Zaphrentis sp	c	Naticopsis sp	c
Aulopora sp	r	Parodiceras discoideum	c
Chonetes cf. mucronatus	r	Bactrites cf. aciculum	c
Ambocœlia cf. nana	a	Tentaculites gracilistriatus	c
Buchiola halli	a	Phacops cristata var. pipa	a
Pterochænia fragilis	c		

This faunule, it will be noted, indicates some departure in its composition from those previously listed and shows a greater contrast with the typical Onondaga facies than any of those hitherto recorded.

The presence of *Pterochænia fragilis*, *Buchiola halli*, and *Parodiceras discoideum* might suggest that it represented the Marcellus or Hamilton were it not for the presence of the Onondaga trilobite, *Phacops cristata* var. *pipa*, which has not been recorded from beds younger than the Onondaga; for the two lamellibranchs named are known to have a long range, *Pterochænia fragilis* occurring in the Marcellus, Hamilton, and Portage in New York. Moreover, the faunal succession also suggests its Onondaga age. Though it is possible that this faunule represents the Marcellus it is placed provisionally with the Onondaga fauna.

In the black shale comprising the next division of the section the fauna seems to be limited to a single species, *Schizobolus concentricus*, which occurs in abundance. This fauna is followed in the more sandy beds, *g*, higher up by a Portage fauna in which *Paracardium doris* is the dominant species. In the faunule from Little Moccasin Gap, next to be given, the intrinsic evidence of the fauna points unmistakably to its Onondaga age. An important fact about the Little Moccasin Gap faunule in this connection is that it is immediately followed by black shale in which *Schizobolus truncatus*, as in the Little Walker Creek section, is the most abundant if not the only species. Thus both of these Onondaga faunules, though somewhat diverse in type, are directly followed by the *Schizobolus truncatus* fauna.

Little Moccasin Gap.—About 50 miles southeast of the Little Walker Creek section, at Little Moccasin Gap, 9 miles northwest of Abington, the greater portion of the Devonian section is exposed. The lower portion of the section as exposed in the vicinity of the gap is as follows:

Little Moccasin Gap section (station 71).

	Feet.
e. Greenish, buffish, and brownish clay shale, with *Buchiola speciosa*, etc. (Portage fauna)	15
d. Black, gray, and greenish clay shale, fissile and carbonaceous where black and more or less blocky elsewhere	200±
c. Hard blue argillaceous limestone, weathering to a buff soft blocky kind of shale similar to that generally representing the Onondaga. *Chonetes carinatus*, *Chonetes mucronatus*, etc. (rich fauna)	5±
b. Hard cherty and sandy limestone, chert predominant and rocks generally appearing as a chert bed	2–4
a. Dark lead-gray to brownish sandstone	6+

The greenish shales, *e*, at the top of the section contain a Portage fauna. In the fissile black shale element of the beds below, *d*, *Schizobolus truncatus* occurs in abundance, but apparently no other species. The Onondaga is represented by about 5 feet of argillaceous limestone, *c*, at the base of the shales, from which the following species were obtained:

Stictopora sp	c	Spirifer disparalis	c
Pholidops cf. areolata	r	Meristella nasuta	r
Strophalosia cf. truncata	r	Pentagonia unisulcata?	r
Chonetes mucronatus	c	Pterinea sp. undet	c
C. arcuatus	a	Cypricardinia indenta	c
Ambocœlia umbonata	r	Leiopteria cf. bigsbyi	r
Schuchertella pandora	r	Conocardium cf. cuneus var. nasutum	r
Rhipidomella vanuxemi	r	Odontocephalus ægeria?	r
Atrypa reticularis	r	Leperditia? cf. subrotunda	r
Stropheodonta cf. patersoni	c	Bythocypris favulosa	c

Mendota.—About 15 miles south of Little Moccasin Gap, at Mendota, another collection was obtained, representing a facies of the Onondaga fauna very similar to that shown by the preceding list. The stratigraphic relations of the beds holding the fauna are similar to those which have been described at Little Moccasin Gap. Near the head of a ravine northwest of the schoolhouse at Mendota the rather coarse gray or brownish sandstone is followed by about a foot of hard blue argillaceous limestone weathering to soft fine-textured shaly rock of light-buff color. The sandstone appears to lie within the limits of Campbell's Hancock limestone;[1] the limestone is included in the Chattanooga shale of the folios on that region. The following species were collected from the limestone (station 72 *l*, Mendota, Va.):

Zaphrentis sp	r	S. varicosus	r
Crinoid stems	a	Schuchertella pandora	r
Strophalosia truncata	r	Conocardium sp	r
Pholidops cf. areolata	a	Cypricardinia indenta	r
Chonetes lineata	r	Tentaculites scalariformis	r
C. mucronatus	c	Coleolus cf. tenuicinctum	r
C. arcuatus	a	Phacops cristata var. pipa	c
Stropheodonta sp	r	Acidaspis callicera	r
Camarotœchia sp	r	Acidaspis sp	r
Anoplia nucleata	a	Phæthonides gemmæus	r
Meristella nasuta	r	Lichas (Arges) contusus	r
Stropheodonta patersoni	r	Bythocypris favulosa	c
Spirifer cf. fimbriata	r	Bollia obesa	c

The beds following this fauna are black fissile shales having a thickness of more than 100 feet. The fauna characterizing these black shales (station 72*k*, Mendota, Va.) is indicated by the following list:

Schizobolus concentricus	a	Tentaculites sp	r
Chonetes mucronatus	c	Actinopteria sp	r
Styliolina fissurella	a		

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[1] Campbell, M. R., Folios 59, 12, Geol. Atlas U. S., U. S. Geol. Survey.

In this, as in the two preceding sections, *Schizobolus concentricus* is the dominant species of the fauna following the Onondaga fauna. Instead of appearing alone, however, as in the other sections, it is here associated with species common in the Marcellus shale. *Schizobolus concentricus* has been generally regarded as a Genesee species and was recorded only from the Genesee by Schuchert.[1] In the Eighteen Mile Creek section, however, Grabau[2] reported it to be "absent or unknown in the Genesee horizon but present in the Moscow shale below Genesee." More recently this species has been recorded from the Marcellus at Lancaster, N. Y.[3] The Mendota section affords another example of its occurrence with a fauna of earlier horizon value than the Genesee. Marked uniformity in conditions of sedimentation prevailed in Virginia and West Virginia from the end of the Onondaga to the beginning of Portage sedimentation, as is attested by the uniform character of the black shales representing this interval in the sections. Hence the diverse faunas which characterize the Marcellus, Hamilton, and Genesee in central New York can not be expected in this region. In southwestern Virginia there is found, instead, between the Onondaga and Portage faunas, a fauna which in some sections appears to consist solely of the one species *Schizobolus concentricus*, although in places it is associated with a few other fossils, as shown in the last list of species given. This occurrence of the Onondaga fauna carries its southern range to within 8 miles of the Tennessee boundary. The fissile black shale which follows the lighter colored shales holding the Onondaga fauna in Virginia continues on across Tennessee into Georgia and Alabama. In Tennessee, however, the Onondaga fauna has not been found and is believed to be absent. At Clinch Mountain, northwest of Rutledge, *Schizobolus concentricus* is abundant in the Chattanooga shale.

Big Stone Gap.—In the region northwest of Mendota the principal change in the lower part of the Devonian section consists in the great thickening of the series of beds called the Hancock limestone. A thickness of 180 to 275 feet is credited to this formation in the Estillville quadrangle by Campbell,[4] who describes the formation as "blue fossiliferous limestone, very sandy at top and bottom." A section intended to illustrate the relation of the upper part of these beds to the black shales, together with a list of one of the faunas characterizing them, has been published by Kindle.[5] Apparently both Campbell and Kindle overlooked a series of interbedded gray limestones and black cherts which lie just above the sandy beds of the Hancock, separating them from the black shales above. These uppermost limestones with their black cherts present a striking physical resemblance to the typical Onondaga limestone of New York State. They present, moreover, a marked lithologic contrast to the beds which immediately precede them. The latter, where leached by surface waters, in many places resemble sandstone more than limestone and in many places hold thin bands of quartz conglomerate in which pebbles 1 to 2 inches in diameter are not rare. The faunal contrast is as marked as the lithologic. The fossils present are almost entirely corals, which occur in such numbers as to form practically a coral reef. The fauna of these cherty limestones indicates that they should be correlated with the Onondaga limestone. In the Estillville folio they were included in the Chattanooga shale.

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[1] Synopsis of American fossil Brachiopoda: Bull. U. S. Geol. Survey No. 87, 1897, p. 372.

[2] Grabau, Amadeus, Bull. Buffalo Soc. Nat. Sci., vol. 6, 1899, p. 17.

[3] Wood, Elvira, Bull. New York State Mus. No. 49, 1901, p. 157.

[4] Estillville folio (No. 12), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

[5] Williams, H. S., and Kindle, E. M., Contributions to Devonian paleontology, 1903: Bull. U. S. Geol. Survey No. 244, 1905, p. 28.

Reexamination of the section at Big Stone Gap previously described by Kindle from exposures along the Louisville & Nashville Railroad, on the northwest side of town, failed to disclose the presence there of the beds under discussion. In that section the crumbling sandy beds of the Hancock limestone appear to be overlain directly by the black shale. This seems to indicate the local absence, probably through erosion, of the coralline limestone. The stratigraphic relations of this limestone and chert bed are shown in the following section, which is exposed under the old woolen mill on the southeast side of Big Stone Gap:

Woolen Mill section, Big Stone Gap.

	Feet.
Fissile black shale	20
Gray coralline limestone and interbedded black chert	8
Buff or brownish, somewhat calcareous sandstone	20+

Another locality where this bed may be advantageously studied is 1½ miles northeast of Big Stone Gap, at the cave entrance on the opposite side of the highway from the sink of Wild Cat Creek, where a greater thickness of both the Hancock limestone and the Chattanooga shale is exposed.

Wild Cat Creek section.

	Feet.
Fissile black shale	35+
Gray limestone and interbedded gray or black chert; corals in great abundance	5
Gray subcrystalline limestone, with much sandy and argillaceous matter in the upper part; many of the higher beds weather to a buff fine-grained sandstone; fossils abundant	60
Hard dark close-grained limestone, with very few fossils	50

The following fauna, which characterizes the coralline limestone, is identical in the Wild Cat Creek and Woolen Mill sections:

Zaphrentis cornicula.
Z. cf. prolifica.
Cystiphyllum americanum.
C. sulcatum.
Blothrophyllum decorticatum.
B. americanum.
Heliophyllum halli.
H. cf. annulatum.
Diphyphyllum cf. gigas.
Cladopora cf. expiata.
C. cf. bifurca.
C. crassa.
Syringopora hisingeri.
S. cf. maclurei.
Favosites emmonsi.
F. hemisphericus cf. turbinatus.
F. epidermatus.
F. canadenses.
Dendropora cf. neglecta.
Vermipora cf. fasciculata.
Aulopora sp.

The above list comprises the total fauna found in this bed, with the exception of a few crinoid stems and a couple of small fragments of undetermined brachiopods. Most of these species are such characteristic Onondaga corals that they afford conclusive evidence of the Onondaga age of the limestone. They represent a coral reef which locally seems to have practically excluded other forms of marine life. This coral fauna represents a facies which differs as markedly from that found in the Onondaga shale of the middle Allegheny region as does the Onondaga fauna of the Jeffersonville limestone reef at the Falls of the Ohio. It is the result, doubtless, of bathymetric and other conditions similar to those which produced the coral fauna at the Falls of the Ohio and, like that fauna, it probably represents a portion of the sea bottom which was shallower than that occupied by the Onondaga fauna of the middle Allegheny region.

The fauna of the lower part of the Hancock limestone includes, according to Bassler,[1] *Leperditia alta*, *Klœdenella clarkei*, and other fossils which he considers of Manlius age. Between this fauna and the coral fauna listed above another fauna distinct from both occupies most of the upper part of the Hancock limestone. Schuchert[2] regards this fauna as representing the New Scotland and Coeymans. Bassler,[1] recognizing the unusual character of the fauna, seems to regard it as of Coeymans age. The rather unique character of this fauna in the upper part of the Hancock limestone invites a more extended discussion in offering any final opinion as to its age than is here warranted. The most closely related fauna known to me is that in the Armuchee chert at Rome, Ga., but a final correlation must await more complete study, which it is expected will be presented in a future paper. It is sufficient at present to state that whatever its exact correlation may be the fauna just below the coral fauna is very different from the Oriskany fauna generally found at the base of the Onondaga to the northeast.

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[1] Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Bull. Virginia Geol. Survey No. 2-A, 1909, p. 273.

[2] Am. Jour. Sci., 4th ser., vol. 19, 1905, p. 460.

In the lower part of the black shale following the Onondaga *Schizobolus concentricus* and *Lingula ligea* occur abundantly at most localities about Big Stone Gap. To these species, which were heretofore the only known representatives of the black shale fauna of this region, my recent collections have added other brachiopods and a rich conodont fauna. These will be listed and described in a later paper on the higher Devonian faunas of the Allegheny region.

The occurrences of the Onondaga fauna at Big Stone Gap and Mendota are the most southerly appearances of the fauna which I have been able to recognize in Virginia. It is not improbable that the fauna may cross the Tennessee line into Hancock County, although I have failed to find it on the Tennessee side. South of Hancock County in eastern Tennessee the Onondaga fauna is undoubtedly absent, and this time interval is unrepresented in the sediments.

AGE OF THE FAUNA.

GENERAL CONSIDERATIONS.

In the preceding pages the stratigraphic relations of the several faunules which occur in the shale and impure limestone bands immediately following the Oriskany sandstone over most of the area have been set forth in detail, and the stratigraphic and paleontologic evidence as to their unity or membership in a common fauna has been given. The age of this fauna as a whole may now be considered.

This general consideration of the whole fauna is important because many individual faunules taken alone do not furnish entirely satisfactory evidence as to their age. In this respect, however, the faunules of this fauna are not peculiar or different from those of various other faunas which might be cited. Illustrations of this fact may be found in the faunules of the Onondaga fauna of New Jersey as listed by Weller.[1] The faunule 2B given by Weller, for example, taken alone affords no clear evidence of the Onondaga, but when considered in connection with other faunules from the same horizon it leaves no doubt of its Onondaga age.

Examination of the list of species occurring in this fauna shows that the evidence which they afford as to its age is somewhat complex and requires detailed analysis to indicate its exact significance. The fauna includes species that are known in the Oriskany, the Onondaga, the Marcellus, and the Hamilton formations. Before considering the evidence in detail, certain important general factors which enter into the problem of age may be noted.

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[1] Weller, Stuart, Paleontology of New Jersey, vol. 3, 1903, p. 103.

It has been shown that the strata holding this fauna occupy a stratigraphic position similar to that of the Onondaga of central New York, being followed above by the Marcellus shale and resting upon the Oriskany sandstone. (See Pl. I.) South of New York, however, the Onondaga formation includes two distinct lithologic elements—limestones and shales, the latter in places including black shales, which approach in appearance the Marcellus shale. In these shales are certain species, like *Styliolina fissurella* and *Bactrites aciculum*, which are generally associated in the New York Devonian sections with dark shales. Although these two species are familiar forms in the Marcellus shale, they recur above it in the Devonian whenever shales of the Marcellus type appear in the section. Since these species recur above the Marcellus in the Genesee and Portage it is to be expected that they will probably occur below it wherever shale of the type with which they are always associated appears earlier than the Marcellus in the Allegheny province. In determining the age of shales of this type such species can therefore have little or no weight as evidence of Marcellus age if they are associated with species which are elsewhere known only from beds of Onondaga or earlier age. In most of the faunules these species, which have been recorded as of Marcellus or later age, are associated with species that are not known to occur later than Oriskany or Onondaga time.

So strong is the Oriskany element in the fauna that, if the stratigraphic evidence did not clearly show it to be above the Oriskany sandstone, much paleontologic evidence could be adduced for considering the fauna to be of Oriskany age. Critical examination of the faunules in connection with the stratigraphic evidence, however, affords satisfactory grounds for correlating the strata and the fauna under consideration with the Onondaga limestone and its fauna.

BIOLOGIC GROUPS.

A comprehensive view of the intrinsic evidence which the fauna will afford regarding its age can perhaps be best secured by taking up for separate consideration the several biologic groups comprising it in their natural order. The value of the evidence furnished by these different groups will be found to differ, partly because of factors inherent in the faunas themselves, and partly because of fortuitous conditions relating to their collection or condition of preservation.

The trilobites, for instance, furnish the most important evidence given by any single group, not only because they are widely distributed, but because, being the most highly organized invertebrates in the Paleozoic faunas, they were correspondingly sensitive to the changing marine conditions which accompanied the development of successive formations and faunas. The trilobites are therefore the most trustworthy index fossils and horizon markers. Their comparatively slight tendency to recur or range beyond their normal horizon is well illustrated in the Chemung of New York State by the recurrent Hamilton fossils, which include many species of Brachiopoda and Pelecypoda, but only one species of the extensive Hamilton trilobite fauna.

The Crinoidea fail to appear in the lists of species here considered, not because the group is unrepresented in the fauna, but because the conditions were generally unfavorable to the preservation of determinable parts.

As might be expected in sediments in which shales are the prevailing element, corals are poorly represented. Only one species is at all common except in the extreme southwestern part of Virginia, where a rich coral fauna containing many index fossils of the typical Onondaga fauna is found. Owing, however, to the small area over which these corals occur they may be omitted altogether from the discussion of the fauna as a whole. If the fauna of this southwestern facies be left out, the evidence furnished by the Cœlenterata on the question of the age may be considered negligible.

The Bryozoa form another group that plays a small rôle in the fauna for fortuitous reasons. This class of fossils occurs in a fairly satisfactory state of preservation at but two or three localities visited, and no special pains were taken to obtain them at these points.

BRYOZOA.

The following short list of the Bryozoa, although far from complete, includes the species which were collected and studied:

Cystodictya gilberti (Meek).
Polypora cf. distans (Hall).
P. cf. hexagonalis (Hall).
Coscinium sp. undet.
Fenestella sp. undet.
Hederella sp.

Cystodictya gilberti occurs in the collections from southwestern Virginia and northeastern Pennsylvania and is one of several species indicating the identity of the horizon considered in these widely separated localities. As indicating the age of the fauna its evidence is significant, since it has been recorded from but one Devonian formation—the Onondaga limestone. The other species in the list do not represent specific determinations, but two of them—*Polypora* cf. *distans* and *P.* cf. *hexagonalis*—are closely allied to if not identical with the species with which they are compared, both of which are Onondaga fossils. The evidence of the Bryozoa therefore points toward the Onondaga age of the fauna.

BRACHIOPODA.

The species which comprise the brachiopod element of the fauna are shown in the following list:

Lingula cf. ligea Hall.
Pholidops cf. areolata Hall.
Orbiculoidea lodiensis var. media Hall.
O. lodiensis.
Anoplia nucleata.
Strophalosia truncata (Hall).
Productella navicella Hall.
Chonetes hemisphericus Hall.
C. cf. setigerus (Hall).
C. mucronatus Hall.
C. buttsi n. sp.
C. rugosus n. sp.
C. arcuatus Hall.
Atrypa reticularis.
Stropheodonta perplana (Conrad).
S. patersoni Hall.
S. inequistriata (Conrad).
Leptænisca australis n. sp.
Leptæna rhomboidalis (Wilckens).
Schuchertella pandora (Billings).
S. cf. perversa.
Pholidostrophia pennsylvanica n. sp.
Dalmanella lenticularis (Vanuxem).
Rhipidomella vanuxemi (Hall).
Ambocœlia umbonata.
A. cf. nana.
Cyrtina hamiltonensis Hall.
Spirifer acuminatus (Conrad).
S. varicosus Hall.
Reticularia cf. fimbriata (Conrad).
Pentagonia unisulcata (Conrad).
Anoplotheca acutiplicata (Conrad).
A. camilla.
Meristella nasuta (Conrad).
Nucleospira concinna Hall.
Cranæna cf. romingeri Hall.

The testimony of the brachiopods as to the age of the fauna can be brought out in one way by comparing the above list with lists of brachiopods from four of the Middle and Lower Devonian formations at a representative Devonian locality in eastern New York. Grabau's lists[1] of the several faunas of the Devonian of the Schoharie Valley give the faunas of the Devonian formations from Marcellus to Oriskany, which, though incomplete, are fairly representative of these several faunas. Numerical comparison of the identical brachiopod species named in these several lists with those in the list above should indicate the fauna with which its affinity is strongest.

Comparison with Grabau's list of "fossils of the Onondaga limestone of the Schoharie region"[2] shows that 33⅓ per cent of the brachiopods in the fauna under discussion, or about 50 per cent of the brachiopods in Grabau's list, are common to both lists. In the Schoharie list, as in the one above, there are some species which occur more frequently in the Hamilton than in the Onondaga. *Cyrtina hamiltonensis* is a representative of this class.

Similar comparison with the brachiopods in Grabau's list from the Hamilton formation[3] in the Schoharie region shows only six species common to the two lists—about 22 per cent of the Allegheny species and less than 25 per cent of Grabau's species.

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[1] Bull. New York State Mus. Nat. Hist. No. 92, 1906, pp. 317–332.

[2] Idem, p. 328.

[3] Idem, p. 329.

Comparison with the Marcellus species of brachiopods in the Schoharie Valley as recorded by Grabau reveals a still greater degree of dissimilarity, only two species, or 6½ per cent, being common to the two lists.

The Oriskany fauna of the Schoharie region as reported by Grabau includes no species common to the two faunas.

The foregoing comparison of the brachiopod element of this fauna with that of four Lower and Middle Devonian formations in the Schoharie region shows very clearly that numerically the relationship to the Onondaga fauna is decidedly the strongest.

Although this comparison of the brachiopods of the fauna with the representative lists of the Onondaga and Hamilton brachiopods in the Schoharie Valley is strongly suggestive of the Onondaga age of the fauna, it will be more convincing to examine in detail the horizon values of the several species composing the list. The data indicating the known range of the several species has been compiled from Schuchert,[1] and supplemented by examination of many more recent special papers.

Exclusive of new and doubtfully determined species the list on page 56 contains twenty-four species of brachiopods which are specifically determined. Nine of these are recorded from the Marcellus, Hamilton, and other later horizons, but not from the Onondaga or earlier horizons. Eleven are common to Onondaga and later faunas. Four are known from Oriskany and Onondaga faunas, but from no later horizon. Six are recorded from the Onondaga alone. Not a single species is limited in range to the Hamilton fauna. Briefly summarized, this analysis shows that the list contains seventeen species, which afford no precise evidence as to the horizon represented, not a single characteristic species of the Hamilton, and six species which elsewhere are recorded only from the Onondaga fauna.

The seventeen species treated in this analysis as having no precise value as horizon markers include two species, *Spirifer acuminatus* and *Pentagonia unisulcata*, which have generally been regarded as characteristic Onondaga species. Their occurrence in the Hamilton, however, is so very rare that they may be considered characteristic and normal representatives of the Onondaga in a fauna of this type. Hence it appears that the list contains no guide fossils of the Hamilton and that about one-third of it consists of characteristic Onondaga fossils.

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[1] Schuchert, Charles, Synopsis of American fossil Brachiopoda: Bull. U. S. Geol. Survey No. 87, 1897.

PELECYPODA.

The pelecypod element of the fauna is represented by the following seventeen species:

Grammysia sp.
Palæoneilo cf. constricta.
Buchiola halli.
Nucula cf. corbuliformis.
Nuculites modulatus n. sp.
Lunulicardium curtum.
Pterochænia fragilis.
Pterinea sp. undet.
Conocardium cf. cuneus var. nasutum.
Actinopteria muricata.
Aviculopecten equilatera.
Modiomorpha subalata.
Cypricardinia indenta.
Leiopteria lævis.
Panenka cf. dichotoma.
Panenka cf. multiradiata.
Panenka alternata.

Examination of the observed range of the fossils shows that only four are recorded as Onondaga species, the other thirteen all being known from either the Marcellus or the Hamilton. Taken alone the evidence of this group of fossils numerically would seem to point to the Marcellus age of the fauna—in the opposite direction from that of the preceding group. It includes, however, one species, *Panenka alternata,* which is unknown above the Onondaga. In explanation of the apparent conflict between the evidence furnished by the Pelecypoda, on the one side, and by the Brachiopoda, Trilobita, and other groups, on the other, the fact may be cited that only a comparatively small pelecypod fauna is known from the typical or limestone facies of the Onondaga. As an example of the relative abundance of the Pelecypoda in the Hamilton and Onondaga formations, or at least of the relative amount of recorded information at an average locality, attention may be directed again to Grabau's lists of the Hamilton and Onondaga fossils in the Schoharie Valley.[1] The Hamilton list includes seventy-five species of Pelecypoda, whereas the Onondaga list includes but one. Hall undertook to describe "all the well-known and determined species of Lamellibranchiate shells from the Upper Helderberg (Onondaga), Hamilton, Portage, and Chemung groups";[2] but this work describes only a very small percentage of Onondaga Pelecypoda and a very large percentage of Hamilton species. The relative abundance of Pelecypoda in the lists of fossils obtained from these two formations seems to depend largely on the fact that one is a nearly pure limestone and the other is usually some type of shale. Lists of fossils from other Paleozoic horizons appear to bear out the observation that the pelecypods were most abundant under conditions favorable to the accumulation of shales and sandstone and least abundant in clear waters. In an Onondaga facies similar to the usual Hamilton facies as great a percentage of Pelecypoda as of Brachiopoda common to both horizons might reasonably be expected in any given region. Most of these mollusks, however, would appear in recorded lists as Hamilton species, because the almost uniformly calcareous Onondaga rocks which have furnished the recorded fauna of the Onondaga represent a habitat that was comparatively unfavorable for these mud or sand-bottom loving creatures. In the sediments and fauna under consideration the rocks represent a facies which approaches much more closely to the Hamilton than to the usual Onondaga type, and it is natural that the Pelecypoda should have an apparent Hamilton aspect. They appear here for the first time in pre-Hamilton rocks because, for the first time, conditions were favorable to their existence.

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[1] Bull. New York State Mus. No. 92, 1906, pp. 328-331.

[2] Paleontology of New York, vol. 5, pts. 1 and 2, 1885, p. vii.

Although the pelecypod fauna is deficient in positive elements indicating its Onondaga age it affords negative evidence of its pre-Hamilton age in its entire lack of those Pelecypoda which are generally considered to belong among the distinctly characteristic Hamilton species. Some of the characteristic Hamilton shells which are conspicuously absent are *Modiomorpha myteloides*, *Cypricardella bellistriatus*, and *Pterinea flabella.* The absence of these common characteristic Hamilton pelecypods is as significant of the pre-Hamilton age of the fauna as is the entire absence of *Tropidoleptus carinatus* from the brachiopod fauna.

GASTROPODA AND PTEROPODA.

The Gastropoda and the Pteropoda contribute, respectively, fourteen and eleven species to the fauna, but the evidence they furnish concerning the age of the fauna is not proportionate to the number of species represented. This evidence is not sufficiently definite to require detailed consideration here. The gastropod list contains *Bellerophon pelops*, a fossil not recorded above the Onondaga limestone in the New York section. The pteropod group includes the species *Tentaculites scalariformis*, which is also an Onondaga species. Associated with these species, however, are others that are better known at Hamilton than at Onondaga horizons. Hence the evidence afforded by these groups, considered independently, is indecisive.

CEPHALOPODA AND CONODONTS.

The few species represented by the cephalopods and the conodonts in this fauna are also inconclusive and may be passed without discussion.

OSTRACODA.

The fossils collected include many undetermined Ostracoda and probably several new species, which are necessarily omitted from the fauna as listed in this paper. The others are as follows:

Leperditia? cf. subrotunda.
Bollia ungula.
B. obesa.
Bythocypris favulosa.
Octonaria stigmata.
Ulrichia conradi.
Craterellina n. gen. n. sp. (MS.).[1]

In order to ascertain what light this group of fossils will throw on the age of the whole fauna, inquiry may be made as to their recorded range in regions outside the Allegheny province. One species, *Bythocypris favulosa*, has not been reported subsequent to its discovery at New Bloomfield by Claypole and may be omitted from consideration. Of the remaining six species one, *Ulrichia conradi*, has been recorded from the Hamilton and the other five from the Onondaga. One of them, *Bollia ungula*, has been reported also from the lower Oriskany by Ulrich and Bassler.[1] Thus we find that more than 70 per cent of the species known in other regions are Onondaga. Whatever weight of evidence the one Hamilton species might carry for a post-Onondaga age is more than offset by the presence of the one Oriskany species and of a genus not hitherto recorded from any horizon later than the Oriskany. It is noteworthy that the two species recorded from the Marcellus in western New York[2] are lacking and that the list includes no ostracode species known to occur in the Marcellus shale.

Perhaps no more striking evidence of the early Devonian or pre-Marcellus aspect of the ostracode fauna can be cited here than the fact that an expert student of this group was strongly inclined, after a preliminary examination of this part of the fauna alone, to regard it as representing an Oriskany horizon. One of the ostracode species suggesting an early Devonian horizon is a representative of the remarkable new genus *Craterellina* (MS.) described by Ulrich and Bassler from the lower Oriskany[1] and unknown elsewhere from beds later than the Oriskany.

TRILOBITA.

The trilobites listed in this paper include a considerable number of species hitherto unknown south of New York State. These furnish most important evidence as to age, for with comparatively few exceptions Devonian trilobites do not cross formation boundaries in their range. From the Onondaga limestone of New York, Hall and Clarke have recognized forty-nine species of trilobites, of which only one occurs in the Helderberg limestone, three in the Oriskany sandstone, and only a single characteristic species ranges upward into the Hamilton.[1] That the results of more recent collections have not altered materially these conclusions is shown by examination and comparison of Grabau's lists of the trilobites in the Onondaga and the Hamilton formations of the Schoharie region.[2] Inspection of these lists shows not a single species common to the two. From the Marcellus and the "Agoniatites limestone" no trilobites are recorded by Grabau. A somewhat similar result is obtained on comparing the trilobites recorded by Van Ingen [3] from the Oriskany at Rondout and Glenerie, N. Y., with the New York trilobite fauna of the Onondaga as given by Hall and Clarke; only one species is common to the two lists. These citations of some of the more essential recorded data regarding the range of the Onondaga trilobites afford a basis from which to judge the significance of the large percentage of Onondaga species of the trilobites of the fauna under consideration.

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[1] Ulrich, E. O., and Bassler, R. S., Rept. Maryland Geol. Survey (in press).

[2] Clarke, J. M., Bull. New York State Mus. No. 49, 1901, p. 131. Wood, Elvira, idem, pp. 142–173.

The following list includes the species which have been recognized in the fauna:

Acidaspis callicera.
Phæthonides gemmæus.
Lichas (Arges) contusus.
Phacops cristata.
P. cristata var. pipa.
P. rana.
Conolichas hispidus?
Cyphaspis cf. stephanophora.
Odontocephalus ægeria.
O. selenurus.
Dalmanites (Coronura) aspectans?
D. sp. undet.
D. (Cryphæus) cf. boothi var. calliteles.

The above list of thirteen species contains three trilobites known in the Hamilton fauna. One of these, *Phæthonides gemmæus*, is the species which Hall and Clarke record as common to the Onondaga and Hamilton faunas in New York. The specific identity of another, *Dalmanites* (*Cryphæus*) cf. *boothi* var. *calliteles*, is not definitely determined; if it is the species with which comparison is made, it represents its first reported occurrence at a horizon earlier than the Hamilton. The third species, *Phacops rana*, is one of the very few Devonian trilobites having a wide range. It has its maximum development in the Hamilton but is known to range as high as the Chemung. It has been doubtfully reported from the Onondaga limestone in New York.[4] In view of its great range its occurrence here is without special significance in reference to the age of the fauna. All of the other ten species are characteristic Onondaga trilobites. One of these, *Odontocephalus ægeria*, which is unknown above or below the Onondaga horizon, is one of the most widely distributed species in the fauna. The important and decisive fact which examination of the trilobites of the fauna discloses is that all the definitely determined species, with the exception of two which have been previously recorded from both the Onondaga and the Hamilton, are characteristic Onondaga species. This evidence of the Onondaga age of the fauna appears to be complete and conclusive.

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[1] Paleontology of New York, vol. 7, 1888, p. xviii.
[2] Bull. New York State Mus. No. 92, 1906, pp. 329, 331.
[3] Idem, No. 69, 1903, p. 1208.
[4] Paleontology of New York, vol. 7, 1888, p. 25.

CONCLUSION.

The evidence relating to the age of the fauna is both stratigraphic and paleontologic. It has been shown (pp. 11–19) that the calcareous shales holding this fauna are in most places underlain in the sections by the Oriskany sandstone and are everywhere overlain by the dark fissile and comparatively barren shales of the Marcellus. These two limiting formations exhibit in general essentially the same lithologic characters throughout New York, Pennsylvania, Maryland, West Virginia, and most of Virginia. Both are, however, much thicker in the southern region than in the type region of the Onondaga limestone in New York. In the Helderberg Mountain region the Onondaga and the Hamilton faunas are separated by 300 feet of comparatively barren dark Marcellus shale and in western New York by shale of about half this thickness, whereas in Pennsylvania and in areas farther south these shales in many places have a thickness of more than 500 feet.

Though the succession from the Onondaga fauna to the Marcellus shale and fauna above is uniform throughout the Allegheny region, as it is in New York, the succession at the base of the fauna is not everywhere precisely the same. In most of the territory the Onondaga rests upon the Oriskany, but in some of the Pennsylvania sections it immediately overlies beds representing the Esopus shale and possibly the Schoharie as well. In respect to its underlying formation, however, the Onondaga shows less variation in the Allegheny region than in New York where, in different areas, it is found to follow the Manlius, Oriskany, Esopus, and Schoharie. Thus we find that this fauna occupies in the Allegheny region the same relative position in the succession of faunas as the Onondaga formation does in the standard sections of New York. The stratigraphic evidence, therefore, points to the Onondaga age of the fauna.

All of the Devonian faunas are composed of indigenous and exotic species. Each fauna is distinguished from its predecessor by a greater or less number of the latter class—immigrants from some alien region. This fauna contains a number of indigenous species which have been passed on to it from the Oriskany fauna. Many of these indigenous species are found in the Hamilton also. Some of them, like *Chonetes mucronatus*, range from the Oriskany, where they first appear in eastern America, into the Hamilton. That the fauna does not represent a late phase of the Oriskany is indicated by the presence of a large percentage of exotic species which have been found elsewhere only in the Onondaga formation. On the other hand, the entire absence from the fauna of any of the species which can be regarded as exotic Hamilton species affords decisive evidence against the alternative hypothesis of early or prenuncial Hamilton age. Such species as *Tropidoleptus carinatus*, *Spirifer audaculus*, *Modiomorpha myteloides*, and *Cypricardella bellistriatus* which marked the appearance of the Hamilton fauna in eastern America are conspicuously absent from this fauna, which in this respect shows a striking contrast with the limestone faunas described by Clarke and Wood[1] from the Marcellus shale of New York. Three of the above-named species are recorded in their faunas and plainly indicate a later fauna than the one under discussion here.

Both the faunal and the stratigraphic evidence, therefore, seem fully to warrant the correlation of the fauna with the Onondaga.

PALEOGEOGRAPHIC SIGNIFICANCE OF THE FAUNA.

The faunal and stratigraphic evidence which has been presented calls for a distinct modification of the current conception of the extent of the Onondaga sea in the eastern part of the United States. It is a noteworthy fact that nearly all the contributions to the knowledge of the Onondaga fauna have dealt with a nearly pure limestone fauna. If one were to seek a comprehensive idea of the character of the Onondaga sea and its sediments from the published descriptions of the fauna and the limestones holding it, he would get the conception of a sea in which only limestones were deposited. To anyone who admits that the factors controlling marine sedimentation were essentially the same in Paleozoic and in recent times, a Devonian sea in which only calcareous sediments accumulated is a manifest absurdity. We know of no continental or other seas in which there are not a variety of types of sediment accumulating simultaneously. Papers which have undertaken to deal with this fauna in a large way and weld its evidence into the new science of paleogeography have naturally been influenced by the fact that the only faunas from the Onondaga sea described except that of the Kanouse sandstone ("Newfoundland grit") of New Jersey[2] were limestone faunas. Translated into the form of a paleogeographic map this class of evidence taken alone gives us a sea whose outlines inclose only limestone sediments.

In order to ascertain to what extent recorded evidence will permit the delineation of the shore line of the Onondaga sea within the limits of the Eastern States so that it will appear consistent and rational with reference to the character of the known deposits of that sea, we may consider briefly the principal sources of its sediments. The comparatively thin mass of sediments which accumulated during the whole of the Devonian in the Central States—it was less than 200 feet thick in the Ohio Valley—affords satisfactory evidence that the land area adjacent to the Devonian sea on the west had slight relief and furnished comparatively little sediment at any time during the Devonian. On the east side of the Devonian sea, however, physiographic conditions were very different.

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[1] Clarke, J. M., Marcellus limestones of central and western New York and their fauna: Bull. New York State Mus. No. 49, 1901, pp. 115–138. Wood, Elvira, Marcellus limestone of Lancaster, Erie County, N. Y.: Idem, pp. 139–182.

[2] Weller, Stuart, Paleontology of New Jersey, vol. 3, 1903, p. 104.

The greater part of the Allegheny province was occupied during the Devonian by a broad arm of the sea known as the Appalachian Gulf. Along the eastern border of this sea was deposited the 5,000 to 10,000 feet of Devonian sediments found in the Allegheny region. The chief source of this clastic material has been shown to be a land area known as the highlands of Appalachia, which lay immediately southeast of the Allegheny region. This old land area furnished to the interior Devonian sea of the Appalachian region, between the beginning of Middle Devonian time and the close of the Devonian, a mass of terrigneous sediments which, if restored upon a sea-level plain of Appalachia, "would constitute a mountain range closely resembling in height, extent, and mass the Sierra Nevada of California.[1]

The paleontologic and stratigraphic data which have been presented in preceding pages show that Onondaga sediments are present in the Allegheny region and that they are mainly of noncalcareous or clastic type, as might have been expected from theoretical considerations. The discovery of an Onondaga fauna in the Allegheny region, in the series of drab or dark shales and thin interbedded argillaceous limestones that have been described, thus very materially supplements the hitherto one-sided character of the available data relating to the nature of the fauna and sediments of the Onondaga sea. The sediments holding this fauna are of a character that might naturally be formed on some portion of the Onondaga sea floor, as is indicated by analogy with the processes of sedimentation now in operation in the largest continental seas. We may now consider the bearing of the data which have been cited on the modification of the current conception of the eastern shore line of the Onondaga sea in the eastern United States.

The Onondaga formation extends not far south of Delaware River, according to most of the papers dealing with the stratigraphy of of the Devonian in the Allegheny region, thus giving it a north-south extension of scarcely 200 miles. The evidence which has been presented, however, indicates that the southerly extension of the Onondaga fauna is quite comparable in distance with its westerly extension.

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[1] Maryland Geol. Survey, special publication, vol. 4, pt. 1, p. 62.

The field studies of the writer have shown that the Onondaga fauna in the Allegheny region extends far south of the area in which nearly pure limestones were deposited during Onondaga time, into a region where shale-forming sediments partly or completely dominated those of calcareous type. This fauna has been found in nearly all the sections studied from New York to Tennessee.

The direct bearing of these new data on the paleogeography of Onondaga time is obvious. They indicate the extension of the eastern shore line of the Onondaga sea in a southwesterly direction from southeastern New York to the east of the Allegheny region instead of far to the west of it, as previously drawn in paleogeographic maps, across the States of Ohio, Indiana, and Kentucky. In the light of this new evidence it appears that the eastern shore line of the Onondaga sea trended southwestward across north-central New Jersey and southeastern Pennsylvania. It probably traversed the States of Maryland and Virginia near the present axis of the Blue Ridge. From southwestern Virginia this shore line appears to have trended westward not far from the Kentucky-Tennessee line as far as the valley of Tennessee River, where it resumed its southerly trend.

DESCRIPTION OF THE FAUNA.[1]

CŒLENTERATA.[2]

Genus ZAPHRENTIS Rafinesque.

ZAPHRENTIS cf. SIMPLEX Hall.

Plate II, figure 1.

1843. Cf. *Strombodes simplex.* Hall, Geology New York, Survey Fourth Geol. Dist., 1843, p. 209, fig. 6.

1876. Cf. *Zaphrentis simplex.* Hall, Illus. Dev. Fos., 1876, pl. 21, figs. 5-11.

A few imperfect shale molds and casts of a coral closely resembling and probably identical with this species occur in the collection. The best preserved of these, here figured, exhibits the following features:

Corallum smooth, gently and regularly expanding from the base; deflected near the base; calyx deep.

Distribution.—New Bloomfield, Pa., and Clifton Forge, Va.

Genus PLEURODICTYUM Goldfuss.

PLEURODICTYUM sp. undet.

Plate II, figure 3.

The species of poriferous coral here figured has been found at only two widely separated points—Perry County, Pa., and the James River valley, Va. The occurrence of this peculiar coral at about the same level above the Oriskany at localities so far apart as these has perhaps more stratigraphic than tectological interest, as the material, although indicating clearly the same species at the two localities, hardly justifies reference to any described species. It is comparable with the species illustrated by Davis[3] under the name of *Procteria papillosa* Davis, but is believed to belong to *Pleurodictyum.*

The specimens are contained in a hard drab shale, which preserves none of the original corallite material, showing only shale molds of the individual corallites and of their numerous mural pores, their size and relations.

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[1] No attempt has been made to give complete synonymy except for the Pelecypoda. In other groups the citation of the original description and one or more papers in which figures have been published is given for the convenience of the reader. For additional synonymy reference may be made to Bull. U. S. Geol. Survey Nos. 63, 87, and 173, and to Miller's North American geology and paleontology.

[2] A rich coral fauna of Onondaga age was discovered in southwestern Virginia after the plates and descriptions of species for this paper had been completed. This fauna comprised about 20 additional species, which will be found listed on p. 52.

[3] Kentucky fossil corals, pt. 2, 1885, pl. 41, figs. 15-21.

The best preserved specimen shows a corallum 6 millimeters in diameter composed of six corallites. Base nearly flat; corallites connected by numerous intermural pores. Most of the lateral pore fillings appear as spines in the specimens. The figured specimen shows only four of the original six corallites which belonged to it.

Distribution.—New Bloomfield, Pa., and Clifton Forge, Va.

Genus CYSTIPHYLLUM Lonsdale.

CYSTIPHYLLUM AMERICANUM Edwards and Haime.

Plate II, figure 2.

1843. *Cystiphyllum cylindricum* Lonsdale. Hall, Geology New York, Survey Fourth Geol. Dist., 1843, p. 209, figs. 1, 2.
1851. *Cystiphyllum Americanum.* Edwards and Haime, Polyp. Foss. Terr. Pal., 1851, p. 464, pl. 13, fig. 4.
1876. *Cystiphyllum americanum.* Rominger, Geol. Survey Michigan, 1876, vol. 3, pt. 2, p. 133, pl. 50, figs. 1, 2, and 4.

This is one of the most abundant species in the coral fauna of southwestern Virginia. It is unknown in the shale and argillaceous beds which generally represent the Onondaga in the Allegheny region.

Distribution.—Big Stone Gap, Va.

Genus BLOTHROPHYLLUM Billings.

BLOTHROPHYLLUM DECORTICATUM Billings.

Plate II, figure 4.

1859. *Blothrophyllum decorticatum.* Billings, Canada Jour., 1859, vol. 4, p. 130.
1876. *Blothrophyllum decorticatum.* Rominger, Geol. Survey Michigan, 1876, vol. 3, pt. 2, p. 113, pl. 41, figs. 1 and 2.

This characteristic Onondaga coral is common in an excellent state of preservation in the coral reef fauna of southwestern Virginia.

Distribution.—Wild Cat Creek and Big Stone Gap, Wise County, Va.

ECHINODERMATA.

The presence of crinoids in this fauna is attested by a few crinoid stems and some deeply notched plates; but even these are comparatively rare and no determinable remains of the Echinodermata have been found.

VERMES.

Genus POLYGNATHUS Hinde.

POLYGNATHUS sp. undet.

Plate II, figure 5.

Base slightly arched; teeth nearly uniform in size, 10 or more in number, conical, and acutely pointed. The base has a length of about 3 millimeters and the teeth a height of 0.5 millimeter.

The only specimen observed is incomplete, a portion of the base and the basal portion of some of the teeth having been broken away.

Distribution.—In black blocky shale at Tonoloway, Md.

BRYOZOA.

Genus HEDERELLA Hall.

HEDERELLA sp. undet.

This genus is represented by an undetermined delicate filiform species which occurs in the black shale.

Distribution.—East of Cumberland, Md.

Genus CYSTODICTYA Ulrich.

CYSTODICTYA GILBERTI (Meek).

1871. *Ptilodictya (Stictopora) Gilberti.* Meek, Proc. Acad. Nat. Sci. Philadelphia, 1871, p. 63.

1873. *Ptilodictya (Stictopora) Gilberti.* Meek, Paleontology of Ohio, vol. 1, 1873, p. 194, pl. 18, figs. 1 a–c.

The specimens representing this species display prominently the arching transverse undulations of growth and the radiating longitudinal lines of the mesotheca on most individuals. The cells of the fronds are less perfectly preserved.

Distribution.—Schuylkill Haven, Pa.

Genus COSCINIUM Keyserling.

COSCINIUM sp. undet.

An undetermined species of *Coscinium* in the collection resembles somewhat *C. striatum*, but has larger meshes than that species.

Distribution.—Schuylkill Haven, Pa.

Genus FENESTELLA Lonsdale.

FENESTELLA sp. undet.

A number of poorly preserved specimens comparable with *F. parallella* are included in the collection.

Distribution.—Schuylkill Haven, Pa.

Genus POLYPORA McCoy.

POLYPORA cf. DISTANS (Hall).

1883. Cf. *Fenestella distans.* Hall, Trans. Albany Inst., vol. 10, 1883, p. 166 (abstract, 1881, p. 23).

1883. Cf. *Fenestella (Polypora) distans.* Hall, Rept. State Geologist New York for 1882, 1883, pl. 30, figs. 2–3, ? 6–10, 15, 16.

The collections contain one specimen representing the noncelluliferous face of a frond, which probably belongs to this species.

POLYPORA cf. HEXAGONALIS (Hall).

1883. Cf. *Fenestella hexagonalis.* Hall, Trans. Albany Inst., vol. 10, 1883, p. 169 (abstract, 1881, p. 27).
1883. Cf. *Fenestella (Polypora) hexagonalis.* Hall, Rept. State Geologist New York for 1882, 1883, pl. 31, figs. 14-20.

The specimens provisionally referred to this species agree with *P. hexagonalis* in the superficial characters, which alone can be examined in the material at hand.

Distribution.—Schuylkill Haven, Pa.

BRACHIOPODA.

Genus LINGULA Brugière.

LINGULA cf. LIGEA (Hall).

Plate II, figure 6.

1860. Cf. *Lingula ligea.* Hall, Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 76.
1867. Cf. *Lingula ligea.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 7, pl. 1, fig. 2.

Shell subelliptical, sides parallel, posterior margin gently rounded from the obtuse or slightly pointed beak, anterior margin broadly rounded. Surface covered with fine concentric striæ. The specimens studied show no indication of the obsolescent radiating striæ said by Hall to characterize *L. ligea.*

Distribution.—Abundant in dark shale 2 miles west of Canoe Creek, Blair County, Pa. Less abundant at Ridgeville, W. Va.

Genus ORBICULOIDEA D'Orbigny.

ORBICULOIDEA LODIENSIS var. MEDIA (Hall).

Plate II, figures 9, 10, 11.

1863. *Discina media.* Hall, Sixteenth Rept. New York State Cab. Nat. Hist., 1863, p. 27.
1867. *Discina media.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 20, pl. 2, figs. 25-29.

Shell subcircular or broadly elliptical. Dorsal valve moderately convex normally but commonly much depressed by pressure. Apex pointed and excentric, placed one-third to one-fourth the length of the shell from the posterior margin. Interior of the valve marked, by a weak linear septal ridge about a millimeter in length, just anterior to the apex and in the longitudinal axis of the shell. Ventral valve slightly convex or nearly flat. Foramen making an elevated ridgelike platform in the interior of valve. Surface of shell marked by fine regular striæ with intermediate spaces about twice their width.

Distribution.—Abundant at most localities from northeastern Pennsylvania to northern Virginia.

ORBICULOIDEA cf. LODIENSIS (Vanuxem).

1842. *Orbicula lodensis.* Vanuxem. Geol. New York, Survey Third Geol. Dist., 1842, p. 168, fig. 1.

At one or two localities a shell has been collected which is similar to the preceding but with finer, less elevated and closer spaced concentric striæ. The finer striæ and very faintly marked fine radiating lines seem to identify it with this species.

Distribution.—Mountain Grove, Va.

Genus PHOLIDOPS Hall.

PHOLIDOPS cf. AREOLATA (Hall).

Plate II, figures 7, 8.

1863. Cf. *Pholidops areolata.* Hall, Sixteenth Rept. New York State Cab. Nat. Hist. 1863, p. 31.

1867. Cf. *Pholidops areolata.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 31, pl. 3, figs. 4, 5.

A minute *Pholidops* closely related to if not identical with *P. areolata*, is frequently met with in this fauna.

The shell is subovate, the width of the posterior portion being slightly greater than that of the anterior. Surface marked by strongly lamellose concentric striæ. The mold of the interior of the ventral valve shows a strongly impressed muscular scar, deepest anteriorly, somewhat resembling the impression of a bovine hoof.

Distribution.—Blair County, Pa.; Ridgeville, W. Va.; Clifton Forge, Mendota, and Little Moccasin Gap, Va.

Genus CHONETES Fischer de Waldheim.

CHONETES HEMISPHERICUS (Hall).

Plate III, figures 15, 16.

1857. *Chonetes hemispherica.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 116, figs. 1-3.

Shell hemispherical with auriculate hinge line. Surface covered by regular rounded striæ. Some of these bifurcate toward the middle of the shell, and a few arise as intercalated striæ, but many continue from the beaks to the margin as simple striæ. The striæ number from 40 to 65 in specimens studied. Extremely fine concentric striæ may be observed on some specimens. No spines are preserved in the specimens studied. This species has been recognized at but one locality, where it is abundant. The highly arched ventral valve, auriculate hinge line, and generally simple radiating striæ suffice to establish its identity.

Distribution.—Schuylkill Haven, Pa.

CHONETES cf. SETIGERUS (Hall).

Plate III, figure 17.

1843. Cf. *Strophomena setigera.* Hall, Geol. New York, Survey Fourth Geol. Dist., 1843, p. 180, fig. 2; p. 222, fig. 3.

The specimens here referred to are rather larger than ordinary specimens of *Chonetes setigerus.* The ventral valve is conspicuously arched and is marked by about sixty rounded radiating striæ, most of which arise through bifurcation at various distances from the beak. The specimen figured indicates nearly vertical spines, the two on the right being deflected by pressure. The spine on left of beak indicates their vertical habit, which shows no tendency to the primary lateral deflection generally seen in *C. setigerus.*

Distribution.—Selinsgrove Junction, Pa.

CHONETES MUCRONATUS Hall.

Plate III, figures 13, 14.

1843. *Strophomena mucronata.* Hall (non Conrad), Geology of New York, Survey Fourth Geol. Dist., 1843, p. 180, fig. 3.

Shell moderately convex. Surface of each valve covered by twelve to twenty-four coarse plications, most of which are simple. In some specimens a few of the plications bifurcate near the margin. Less than half the plications originate in the umbonal region or at the beak, the others starting at the hinge line on either side of the beak. Very fine concentric striæ may be seen on exceptionally preserved shells. Two extremely slender spines originate from the hinge line of the ventral valve and extend outward parallel with it and with each other so as to give often the appearance of a single spine, appearing to be the mucronate extension of the hinge line. In some specimens the length of one of these spines greatly exceeds the width of the valves. This species is clearly identical with the Marcellus species originally described by Hall as *Chonetes mucronatus,* but in the character of the spines and in the absence of a nonplicated area at the cardinal angles it differs from *C. laticosta* of the Onondaga which Hall[1] identified with *C. mucronatus.* The spines of *C. laticosta* are much shorter and lack the almost complete parallelism with the hinge line seen in *C. mucronatus.*

Distribution.—*Chonetes mucronatus* is one of the most abundant species in the fauna. It is found nearly everywhere from New York to southwestern Virginia.

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[1] Hall, James, Paleontology of New York, vol. 4, 1867, p. 125, pl. 20, fig. 1.

CHONETES BUTTSI n. sp.

Plate IV, figures 1–4.

Shell semicircular in outline, the ventral valve depressed convex, dorsal valve nearly flat. Surface covered by seventy-five to one hundred fine regular striæ increasing by bifurcation and intercalation. Well-preserved specimens show very fine concentric striæ crossing these. Two or three acicular spines on each side of the beak of the ventral valve extend nearly at right angles to the hinge line. These are remarkable for their extreme and uniform slenderness from base to tip. The outermost pair arise just inside the points of the hinge line and are inclined slightly outward for a fraction of a millimeter at the base; then they assume the vertical direction. The spines generally have a length equal to or greater than that of the shell. One specimen representing a pathologic individual is interesting as showing the development of the spines under unusual conditions. The shell near the left cardinal angle is absent as a result either of failure to develop normally or of having been broken away. This results in nearly half the hinge line on that side of the shell being absent. The three spines belonging on this side of the shell are present, however, and have developed from the margin of the shell, which fortuitously represents the outer portion of the hinge line. The form nearest allied to this species is *Chonetes setigerus*, the main points of difference being in the number of striæ, size, convexity and length of spines. *C. buttsi* has about double the number of striæ of *C. setigerus* and averages about twice its size. The spines of the latter species are also notably shorter than those of the former, and *C. buttsi* is a much more depressed form than *C. setigerus*.

Dedicated to Mr. Charles Butts, of the United States Geological Survey.

Distribution.—This species occurs abundantly 2 miles west of Canoe Creek, Blair County, Pa. It has not been found elsewhere.

CHONETES RUGOSUS n. sp.

Plate IV, figures 5–7.

Shell medium size, transverse in outline, slightly convex on the ventral side. Surface marked by fine closely placed striæ numbering about one hundred. All of the striæ bifurcate before reaching the margin, some of them repeatedly. Six to ten concentric undulations or corrugations cross the striæ. These are strongest in the median and anterior portion of the shell and die out toward the anterior margin. The hinge line is mucronate, the extremities extending considerably beyond the sides of the shell. A strong riblike process or pseudo hinge line arises from the hinge line about midway between the beak and the extremity of the mucronate extension, curves very gently upward from the hinge line, and extends to or beyond its extremities. A peculiar nonstriated earlike process is subtended between the hinge line proper and the pseudo hinge line. This, on the inner surface, is marked by a series of closely spaced diagonal denticulations. Dorsal valve and internal characters are unknown.

The peculiar denticulated earlike expansion posterior to the hinge line distinguishes this from any other *Chonetes*. A single specimen doubtfully referred to this species shows two short outwardly directed spines on each side of the beak. Ordinary spines have not been observed on any other specimens referred to this species.

Distribution.—In soft drab shales at Cumberland, Md.

CHONETES (EODEVONARIA) ARCUATUS Hall.

Plate III, figures 9–12.

1857. *Chonetes arcuata.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 116.

1867. *Chonetes arcuata.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 119, pl. 20, figs. 7 a–f.

Shell semielliptical or semicircular and decidedly gibbous. Surface covered with very fine rounded striæ which increase by bifurcation and intercalation. These number one hundred or more on mature individuals. Very fine concentric striæ cross the radiating striæ. The ventral valve has a well-developed area inclined at about 35° to the plane of the valves. The inner margin of the area is bordered by fifteen to twenty strong crenulations on each side of the beak. A low rounded septum extends from one-third to one-half the distance from the beak to the front of the shell. Well-marked muscular scars lie on either side of the septum, as shown in the figure. The specimens studied vary in size with respect to width from 16 to 30 millimeters.

Distribution.—Abundant at Mendota and Little Moccasin Gap, Va.; not observed farther north.

Genus ANOPLIA Hall and Clarke.

ANOPLIA NUCLEATA Hall.

Plate V, figures 8–11.

1857. *Leptæna nucleata.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 47.

1859. *Leptæna? nucleata.* Hall, Nat. Hist. New York, Paleontology, vol. 3, 1859, p. 419, pl. 94, fig. 1.

Shell small, concavo-convex, and strongly arched. Surface without striæ or plications. Interior of both valves strongly pustulose. Ventral valve very gibbous in the umbonal and median region, beak incurved. In the interior a strong septum extends from the beak about one-third the distance to the front of the shell. In nearly all specimens this septum terminates abruptly. In a few individuals, however, it is continued forward a short distance beyond its normal terminus as a pair of rather faintly developed, divergent, Y-shaped arms. Most of the specimens from Mendota, Va., show molds of the extremely slender tube, which originates on the inner surface of the shell, midway between the beak and the cardinal angle just inside the inner margin of the area, and crosses diagonally the marginal portion of the valve with a slight curve. It terminates at the side of the beak in a minute point, which apparently does not reach the outer surface of the shell.

Dorsal valve moderately and regularly concave. Outer surface marked by a minute tripartate median process just inside the hinge line. This comprises two short divergent lobes and a third median lobe stronger than the lateral one, having a length of about one-third millimeter. The interior of this valve is characterized by two slender, sharp median ridges. These diverge slightly as they extend forward from the base of the cardinal process and terminate about two-thirds the distance from the hinge line to the front. A narrow, elongate muscular scar occupies the posterior half of the space between these ridges. Outside this pair of median ridges is a second pair of poorly defined and very divergent ridges which appear to mark the outer limits of muscular areas.

The peculiar short, tripartite process on the exterior of the dorsal valve of this shell was correctly figured by Hall and Clarke[1] in their work on the Brachiopoda, but in the latest figures[2] of this shell a specimen which is evidently a mold of the exterior of a dorsal valve has been figured by Clarke as an interior.

Distribution.—One of the most widely distributed species in the fauna; collected at Schuylkill Haven, New Bloomfield, and Blair County, Pa.; Tonoloway, Md.; Berkeley Springs and Rees Tannery, W. Va.; Bells Valley, Clifton Forge, and Mendota, Va.

Genus **PHOLIDOSTROPHIA** Hall and Clarke.

PHOLIDOSTROPHIA PENNSYLVANICA n. sp.

Plate V, figures 1, 2.

Shell small, concavo-convex or plano-convex. Ventral valve depressed convex, greatest width at hinge line and salient cardinal angles. Surface without radiating striæ but with some indications of lamellose lines of growth. The impression of a single dorsal valve supposed to belong to this species is slightly concave and shows a very short, slender septum extending 1 millimeter from the hinge line. The collection contains six or seven specimens. An average specimen has a width of 8 millimeters at the hinge line and a length of 6 millimeters.

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[1] Natural history of New York, Paleontology, vol. 8, pt. 1, pl. 20, fig. 16, 1892.
[2] Mem. New York State Mus. No. 9, 1908, pl. 41, fig. 16.

This shell resembles both *P. iowensis* (Hall) and *Stropheodonta hunti* Clarke in its smooth exterior. It is smaller than either of these, however, and does not possess the crescent-shaped ridges which characterize the dorsal valve of *P. iowensis*. The absence of these may leave some doubt as to the propriety of referring this shell to *Pholidostrophia*, but the smooth surface and the general features of the shell strongly indicate its relationship to this group of the Stropheodontas.

Distribution.—Blair County, Pa.; Cumberland, Md.; Ridgeville and Berkeley Springs, W. Va.

Genus **LEPTOSTROPHIA** Hall and Clarke.

LEPTOSTROPHIA PERPLANA (Conrad).

Plate II, figures 12, 13; Plate III, figure 1.

1842. *Strophomena perplana*. Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 257, pl. 14, fig. 11.

Characteristic examples of this species showing the finely striated, slightly concavo-convex shells have been found at two localities. Two of these are here figured.

Distribution.—Schuylkill Haven and Bloomfield, Pa.

Genus **STROPHEODONTA** Hall.

STROPHEODONTA PATERSONI Hall.

Plate III, figures 5, 6.

1857. *Strophomena* (*Strophodonta*) *patersoni*. Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 114, figs. 1-5.

The two specimens referred to this species represent ventral valves semielliptical in outline. The hinge line is marked by very fine and shallow denticulations. The surface has about 20 strong, elevated, and widely separated striæ, most of which originate at or near the beak. Eight to ten very fine striæ occupy the interspaces between the stronger striæ. These interspaces are also interrupted by nodelike elevations, which appear to represent more or less regular concentric wrinkles which do not cross the stronger striæ.

Distribution.—Mendota, Va.

STROPHEODONTA INEQUISTRIATA Conrad.

Plate III, figures 2–4.

1842. *Strophomena inæquistriata.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 254, pl. 14, fig. 2.

The specimens representing this species are all ventral valves showing only external features. The surface is characterized by about 20 strong, sharp, radiating striæ, nearly half of which originate at the beak and the remainder by interstitial addition in the posterior half of the valve. Eight to ten very fine, radiating striæ occupy the space between each pair of stronger striæ at the front of the shell, and half this number in the posterior third of the shell. Extremely fine, concentric striæ cross them. Very fine denticulations border the inner margin of the hinge area.

Distribution.—New Bloomfield, Pa., and Little Moccasin Gap, Va.

Genus SCHUCHERTELLA Girty.

SCHUCHERTELLA PANDORA (Billings).

Plate III, figures 7, 8.

1860. *Streptorhynchus pandora.* Billings, Canadian Jour., vol. 5, 1860, p. 226, figs. 12, 13.

Shell symmetrical subplano-convex, the dorsal valve being moderately convex, the ventral nearly flat or depressed convex. Width about one-fourth greater than length. Surface covered by very sharp, elevated striæ which increase almost entirely by interstitial addition and are crossed by fine, closely placed, crenulating striæ. Ventral valve with a moderately wide area, which is vertically striated and inclined backward. Triangular delthyrium closed by a convex deltidium. Valve slightly convex in the umbonal region and flattened toward the margin. Dorsal valve with a rather narrow area; surface slightly depressed along the median line and near the cardinal angles, regularly convex elsewhere. The three nearly perfect specimens which are referred to this species measure 17, 21, and 26 millimeters in length.

Distribution.—Blair County, Pa.; Little Moccasin Gap and Mendota, Va.

SCHUCHERTELLA cf. PERVERSA (Billings).

1857. Cf. *Orthis perversa.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 137.

1860. Cf. *Orthisina alternata.* Hall, Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 81, figs. 1, 2; p. 112.

The collection includes a number of Schuchertellas which differ most conspicuously from the preceding species by being much smaller and less symmetrical. These are referred provisionally to *S. perversa*.

Distribution.—Schuylkill Haven and Blair County, Pa.; and 3 miles east of Cumberland, Md.

Genus LEPTÆNA Dalman.

LEPTÆNA RHOMBOIDALIS (Wilckens).

1769. *Conchita rhomboidalis*. Wilckens, Nachricht von selten Versteinerungen, 1769, p. 77, pl. 8, figs. 43, 44.

1841. *Strophomena undulosa*. Conrad, Fifth Ann. Rept. Geol. Survey New York, 1841, p. 54.

Distribution.—This well-known species appears to have very scanty distribution in this fauna. It has been found at but two localities: Schuylkill Haven and New Bloomfield, Pa.

Genus STROPHALOSIA King.

STROPHALOSIA TRUNCATA (Hall).

Plate V, figures 5–7.

1843. *Strophomena pustulosa*. Hall [non *Productus pustulosus* Phillips], Geology New York, Survey Fourth Geol. Dist., 1843, p. 189, fig. 4.

Shell small, usually 3 to 8 millimeters in width; concavo-convex, the ventral valve very gibbous and the dorsal valve slightly concave or nearly flat. The ventral valve has a sharply truncated umbo, the truncated face being often slightly concave. Hinge line generally slightly shorter than the greatest width of the shell. Surface of valve covered by irregularly placed short ridgelike tubercles and fine concentric striæ. Slender spines, which are generally missing in the specimens, extended forward from the tubercles. The dorsal valve has the hinge line marked by four or five coarse crenulations or corrugations on each side of the beak. These are seen on both sides of the valve. Surface of valve marked by a few spine bases. Interior of valve with a very slender linear septum extending nearly to middle of valve but not reaching the hinge line.

This is a very common and widely distributed species occurring both in the soft shales and the hard limestone bands of the beds holding this fauna.

Distribution.—Schuylkill Haven, McVeytown, Perry County, and Blair County, Pa.; Cumberland, Md.; Ridgeville, W. Va.; Little Moccasin Gap and Mendota, Va.

Genus **PRODUCTELLA** Hall.

PRODUCTELLA NAVICELLA Hall.

Plate V, figure 3.

1857. *Productus navicellus*. Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 172.
1867. *Productella navicella*. Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 156, pl. 23, figs. 1–3, 9–11.

This species is represented in the collection by two specimens, a fragmentary dorsal valve and a ventral valve. The latter agrees with Hall's figures and description of the species in its gibbous arcuate form, concentric striæ, and spines, but has on its anterior two-thirds costæ which are rather stronger and more regular than indicated by Hall. There are about twenty-one of these at the anterior margin of the shell.

Distribution.—Schuylkill Haven, Pa.

Genus **LEPTÆNISCA** Beecher.

LEPTÆNISCA AUSTRALIS n. sp.

Plate IV, figures 8–12.

Outline variable, as shown in figure; length generally less than width; hinge line somewhat shorter than greatest width of shell. Shell concavo-convex. Ventral valve moderately convex. Surface marked by fine radiating striæ, which are clearly defined only in the anterior part of the shell, and which are crossed by very fine concentric striæ and stronger lines of growth. The muscular pit of the ventral valve is bordered laterally by the dental lamellæ which curve toward each other slightly near the anterior margin of the pit. These lamellæ, as they extend into the shell and away from the surface of the valve, are inclined laterally or away from each other. A short, low median septum extends across the muscular pit from the posterior nearly or quite to the anterior margin of the pit. Molds of the interior of the ventral valve indicate a strongly postulose surface, increasing regularly in coarseness from the margin of the shell to the margin of the muscular impression. The collection contains a single, somewhat imperfect, mold of the interior of a dorsal valve believed to belong to this species. The distinctly bipartite character of the posterior portion of the cardinal process is shown and, somewhat indistinctly, the quadripartite appearance of the anterior portion of the process is seen. A low thick median ridge is present in the anterior part of the mold.

The species of this genus from America[1] previously described are all Helderberg shells. In surface characters they are quite unlike the present species. Two of them appear from the figures to be nonstriated species, but the third, *L. concava,* has radiating striæ of unequal strength, each fifth or sixth being stronger than the intermediate ones. In this species the striæ are all of about equal strength.

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[1] I am informed by Prof. Charles Schuchert (letter of Mar. 14, 1912) that *Leptænisca* is represented in the Silurian of Gotland by *Strophomena rugata* Lindström. He says further, "In this connection we should not forget that *Davidsonia bouchardiana* is undoubtedly closely related to *Leptænisca* and this species may have come directly out of *L. rugata* (Lindström). All these forms appear to be related to *Leptæna rhomboidalis*."

Distribution.—This species occurs in a soft black clay shale about 30 feet above the Oriskany sandstone, 1¾ miles south of Berkeley Springs, W. Va., and in a drab shale about same distance above the Oriskany at New Bloomfield, Pa.

Genus **DALMANELLA** Hall and Clarke.

DALMANELLA LENTICULARIS (Vanuxem).

Plate V, figures 12–16.

1842. *Orthis lenticularis.* Vanuxem [non Wahlenberg], Geology of New York, Survey Third Geol. Dist., 1842, p. 139, fig. 4.

Shell suborbicular, subplano-convex. Cardinal angles obtuse or rounded. Greatest width about one-fourth greater than length of hinge line. Ventral valve with a subcarinate gently rounded median elevation from which the shell slopes regularly to each side. A well-developed muscular impression bordered laterally by strong hinge teeth characterizes the interior. The dorsal valve is depressed convex, with a shallow but distinct mesial depression extending the length of the shell. A strongly marked muscular scar extends to the middle of the valve. A broad, low, and in some specimens indistinct median ridge divides it longitudinally. Posteriorly it terminates in a bifurcated cardinal process.

The entire surface is covered by coarse bifurcating striæ, somewhat irregular in size, grouped in fascicles of four or five. These are crossed by fine concentric striæ. The specimens are somewhat smaller than those figured by Hall.

Distribution.—Abundant throughout most of the region. Has been collected at New Bloomfield and McVeytown, Pa.; Berkeley Springs and Ridgeville, W. Va.; Tonoloway, Md.; and Clifton Forge, Va.

Genus **RHIPIDOMELLA** Oehlert.

RHIPIDOMELLA VANUXEMI (Hall).

Plate V, figures 17–19.

1857. *Orthis vanuxemi.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 135, figs. 1–7.

The specimens referred to this species are a little smaller than the average size of *R. vanuxemi* as seen in the Hamilton. Few of those observed exceed a length of 14 and a width of 16 millimeters, these being the dimensions of one of the larger specimens. In other features than size they correspond closely to the ordinary type of this shell.

Distribution.—McVeytown and New Bloomfield, Pa.; Tonoloway, Md.; and Ridgeville, W. Va.

Genus **LEIORHYNCHUS** Hall.

LEIORHYNCHUS cf. LIMITARE.

1842. Cf. *Orthis limitaris*. Vanuxem, Geology of New York, Survey Third Geol. Dist., 1842, p. 146, fig. 3.

A form closely resembling the characteristic Marcellus species *L. limitare* occurs in one of the Virginia faunules on James River. It has not been observed elsewhere below the Marcellus fauna.

Distribution.—Bells Valley, Va.

Genus **ATRYPA** Dalman.

ATRYPA RETICULARIS (Linn.).

Plate V, figures 24, 25.

1767. *Anomia reticularis*. Linné, Systema Naturæ, ed. 12, vol. 1, 1767, p. 1132.
1867. *Atrypa reticularis*. Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 316, pl. 52, figs. 1–3, 7–12; pl. 53, figs. 3–19; pl. 53A, figs. 22, 23.

This species is not as generally distributed as some others but is rather frequently found in the impure limestone bands. When present it is apt to occur in abundance.

It shows a stage of development of the specific characters similar to that generally seen in the Onondaga fauna. Figures 11 to 13 of Hall's illustrations of the species very well represent the average of the type seen in this fauna both as to size and general proportions. The shell is generally moderately gibbous with a sinus which varies from well developed to a slightly sinuous line at the front. The breadth generally slightly exceeds the length, but the reverse is sometimes seen, as in the specimen figured. The maximum width observed is 27 millimeters.

None of the large highly ventricose or lamellose forms frequently seen in the Devonian of the Central States have been observed in this fauna.

Distribution.—Schuylkill Haven, New Bloomfield, Blair County, Pa.; Little Moccasin Gap, Bells Valley, Va.; Berkeley Springs and Ridgeville, W. Va.

Genus CYRTINA Davidson.

CYRTINA HAMILTONENSIS Hall.

Plate V, figure 4.

1857. *Cyrtia hamiltonensis.* Hall, Tenth Ann. Rept. New York State Cab. Nat. Hist., 1857, p. 166.
1867. *Cyrtina hamiltonensis.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 268, pl. 27, figs. 1-4.

This species is represented in the collection by a ventral and dorsal valve. These exhibit most of the characteristic features of the species—high area and slightly twisted beak in ventral valve, entire surface finely punctate with three or four rounded plications on each side of the fold and sinus. In the extreme weakness and indistinctness of the outer plications, however, these specimens differ somewhat from the forms of *C. hamiltonensis* seen in the Hamilton.

Distribution.—New Bloomfield, Pa.

Genus SPIRIFER Sowerby.

SPIRIFER ACUMINATUS (Conrad).

Plate VI, figures 17, 18.

1839. *Delthyris acuminata.* Conrad, Third Ann. Rept. New York Geol. Survey, 1839, p. 65.
1842. *Delthyris prora.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 263.
1843. *Terebratula acuminatissima.* Castelnau, Essai Syst. Silurien de l'Amérique Septentrionale, 1843, p. 40, pl. 14, fig. 16.

Shell large and ventricose with valves forming a prominent V-shaped elevation at the front. Ventral valve is impressed by a broad deep angular sinus which is greatly extended upward at the front. Transverse striæ mark the concave surface of the ventral valve.

Dorsal valve with sharp angular fold extending from the beak to the front. From the sides of this fold the surface of the valve slopes abruptly to the lateral and anterior margins.

Entire surface of shell covered by strong radiating plications; the intermediate ones bifurcate near the middle of the valve, giving dichotomous plications over the anterior median portion of the shell. These plications are crossed by fine concentric striæ which become somewhat lamellose near the front. Traces of the fimbriate character of these can be seen on a portion of the shell.

Distribution.—Schuylkill Haven, Pa.

SPIRIFER VARICOSUS Hall.

Plate VI, figure 16.

1857. *Spirifer varicosa.* Hall, Tenth Rept. New York State Cab. Nat. Hist., 1857, p. 130.

1861. *Spirifer varicosa.* Billings, Canadian Jour., vol. 6, 1861, p. 255. figs. 63, 64.

This shell is represented by a single well-preserved dorsal valve from Virginia and several fragmentary specimens from Pennsylvania. The hinge line is rather long, terminating in salient angles. On the Virginia specimen there are 10 plications on each side of the fold, all strong and elevated except near the cardinal angles, where one or two are short and indistinct. The median fold is duplicate, a depressed line running down the middle. Strong lamellose striæ cross the plications and fold. Very fine radiating striæ are visible over the best-preserved portions of the shell.

Distribution.—Mendota, Va.; Schuylkill Haven, Pa.

Genus RETICULARIA McCoy.

RETICULARIA cf. FIMBRIATA (Conrad).

1842. Cf. *Delthyris fimbriatus.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 263.

1858. Cf. *Spirifer fimbriatus.* Hall, Geol. Survey Iowa, vol. 1, pt. 2, 1858, p. 505, pl. 4, fig. 5.

The collection contains three small specimens of a *Reticularia* having a breadth along the hinge line of about 5 millimeters and having three to four plications on each side the fold and sinus. These probably represent either immature individuals or a dwarfed form of *R. fimbriata.*

A fourth specimen in the collection is a fragmentary ventral valve comparable and possibly identical with this species. The broad rounded sinus and the four or five rounded plications on each side of it are covered by very fine radiating striæ. These are crossed by concentric striæ which give a slightly fimbriate appearance to the surface of the shell, which, however, is much less pronounced than in ordinary examples of *R. fimbriata.*

Distribution.—Selinsgrove Junction, Pa., and Cumberland, Md.

RETICULARIA cf. MODESTA (Hall).

Plate VII, figure 6.

1859. Cf. *Spirifer modestus.* Hall, Nat. Hist. New York, Paleontology, vol. 3, 1859, p. 203, pl. 28, fig. 1.

The southwestern Virginia collection includes a single brachial valve of uncertain specific identity which is comparable with *R. modesta.*

Distribution.—Mendota, Va.

Genus AMBOCŒLIA Hall.

AMBOCŒLIA UMBONATA (Conrad).

1842. *Orthis umbonata*. Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 264, pl. 14, fig. 4.

1860. *Ambocœlia umbonata*. Hall, Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 71.

The specimens referred to this species show considerable variation and may possibly include an undescribed species. Although one of the most abundant and widely distributed species in the fauna, it generally occurs in soft shales, which furnish rather poorly preserved and often flattened material, whose character scarcely justifies detailed consideration of the variations. Hall[1] states that the surface of this species is marked by "very fine radiating and concentric striæ." In most of the specimens, both in my collection and in other collections bearing the name *A. umbonata*, the surface is smooth. Some specimens, however, show well developed concentric striæ, but none have been observed showing radiating striæ. Shells with a strongly lamellose dorsal valve are not uncommon. These as well as smooth shells frequently show a distinct fold near the front of the dorsal valve.

Distribution.—Schuylkill Haven, New Bloomfield, Blair County, Pa.; Hancock and Cumberland, Md.

AMBOCŒLIA UMBONATA var. cf. NANA Grabau.

Plate V, figures 20–23.

1900. *Ambocœlia umbonata* var. *nana* n. var. Grabau, Sixteenth Rept. State Geologist New York, for 1896, 1900, pp. 276–278, text figs. 3–7.

An *Ambocœlia* with a rough surface marked with numerous minute tubercle-like elevations, apparently spine bases, is represented by a few individuals at two localities. The ventral valve shows a distinct sinus and lamellose surface. The dorsal valve has not been observed. This little shell resembles *A. nana* and is probably identical with it.

Distribution.—McVeytown, Pa., and Rees Tannery, Mineral County, W. Va.

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[1] Natural history of New York, Paleontology, vol. 4, p. 259, 1867.

Genus **ANOPLOTHECA** Sandberger.

ANOPLOTHECA ACUTIPLICATA (Conrad).

Plate VI, figures 1–15.

1841. *Atrypa acutiplicata.* Conrad, Fifth Ann. Rept. New York Geol. Survey, 1841, p. 54.

1862. *Atrypa acutiplicata.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, pl. 11, fig. 17.

The shell is planoconvex in form, orbicular to ovate acute in outline. Shell with six to eight and rarely nine strong angular plications on each valve. On the ventral valve one of these occupies the sinus while two are elevated into a fold on the anterior half of the opposite valve. Posteriorly they are depressed slightly below the adjacent plications. In some gerontic shells the lateral plications show a tendency to become obsolete toward the anterior margin of the shell. Strong lamellose lines of growth cross the plications. This shell as a rule is much depressed in form but occasionally a markedly gibbous form is seen. In one of these the depth of the shell equals more than half its length. There is a considerable variation in the amount of elevation of the folds at the front in shells from the same locality and zone, as will be seen in the figures. Average-sized specimens have a breadth of 12 to 15 millimeters, but a few individuals show a width of 20 millimeters. The breadth usually slightly exceeds the length.

A strong median ridge and dental sockets characterize the interior of the dorsal valve. Corresponding to the latter in the ventral valve are prominent articulating teeth. Slightly anterior to these in the median line is a small well-marked anterior adductor muscular impression. The borders of the posterior impression may or may not be well marked. In many specimens a delicate linear ridge 3 or 4 millimeters in length passes longitudinally through the muscular impression. In some specimens this ridge is very short and is confined to the anterior part of the impression. It may be crossed by a shorter transverse ridge limiting the anterior margin of the ridge and giving it a barblike effect.

Comparison of the types of this species with the specimens from Pennsylvania and from localities farther south shows that the latter undoubtedly belong to this species. For convenience of comparison of the figures one of the types is here refigured in connection with my specimens.

Distribution.—Probably the most abundant and widely distributed species in the fauna. Occurs in most of the collections obtained from New York to southwestern Virginia.

ANOPLOTHECA CAMILLA (Hall).

1867. *Cœlospira concava.* Hall [non Hall, 1863], Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 329.
1867. *Cœlospira camilla.* Hall, idem, pl. 52, figs. 13–19.

This rather diminutive brachiopod is represented by only a few positively determined specimens in the collections. Although comparatively rare, it has been found in both the noncalcareous shale and the limestone in three States, and is probably coextensive with the fauna in its distribution.

Distribution.—Blair County, Pa.; Cumberland, Md.; and Bells Valley, Va.

Genus PENTAGONIA Cozzens.

PENTAGONIA UNISULCATA (Conrad).

1841. *Atrypa unisulcata.* Conrad, Fifth Ann. Rept. Geol. Survey, New York, 1841, p. 56.
1862. *Atrypa unisulcata.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, pl. 11, fig. 10.

This well-known brachiopod is represented in the collections by fragmentary material unsuitable either for figuring or for detailed description.

Distribution.—Schuylkill Haven, Pa.; Little Moccasin Gap, Va. (?).

Genus MERISTELLA Hall.

MERISTELLA NASUTA (Conrad).

Plate VII, figure 7.

1842. *Atrypa nasuta.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 265.
1860. *Meristella nasuta.* Hall, Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 93, figs. 8–9.

This shell is represented by the ventral valves of two mature individuals from southwestern Virginia. The ventral valve is very gibbous, the profile seen from the side forming nearly a half circle. Regularly convex in the median line without trace of sinus. A prominent linguiform extension characterizes the middle of the anterior margin. Surface marked by a few lamellose lines of growth on the anterior half of the shell. Other features not preserved. A deep subquadrate muscular scar marks the interior of the valve.

Distribution.—Mendota and Little Moccasin Gap, Va.

Genus **NUCLEOSPIRA** Hall.

NUCLEOSPIRA CONCINNA (Hall).

Plate VII, figures 3-5.

1843. *Atrypa concinna.* Hall, Geology of New York, Survey Fourth Geol. Dist., 1843, p. 200, fig. 3.

1867. *Nucleospira concinna.* Hall, Nat. Hist. New York, Paleontology, vol. 4, 1867, p. 279, pl. 45, figs. 33-57.

This species is represented by numerous ventral valves, but the dorsal valve has not been observed. Nearly all of the specimens represent casts of the interior, but one silicified specimen shows the bases of the fine setæ over the anterior third of the shell and a highly papillose surface over the remainder. Another of the external characters exhibited in these specimens is a narrow impressed line extending from the beak to the front, varying in intensity in different individuals. The molds of the ventral valve show a narrow, low septum extending from the beak about one-third the distance to the front. The outline of the muscular scars is not very clearly shown in the specimens. Two narrow ridges on either side the septum appear to limit them in the casts.

Distribution.—New Bloomfield and Blair County, Pa.; Berkeley Springs and Rees Tannery, Mineral County, W. Va.; Cumberland and Tonoloway, Md.; Bells Valley and Mendota, Va.

Genus **MARTINIA** McCoy.

MARTINIA ? sp.

A single dorsal valve of undetermined species is doubtfully referred to this genus. It is slightly convex and characterized by a broad, low fold rising scarcely above the rest of the valve.

Genus **CRANÆNA** Hall and Clarke.

CRANÆNA cf. ROMINGERI (Hall).

Plate VII, figures 1, 2.

1863. Cf. *Terebratula romingeri.* Hall, Sixteenth Rept. New York State Cab. Nat. Hist., 1863, p. 48, figs. 22, 23.

Shell small, subcircular or elliptical, the front often truncate. Surface covered with fine concentric striæ, often with strong lamellose lines toward the front. Shell structure punctate. This shell, which may provisionally be referred to *C. romingeri,* occurs in great numbers as flattened shells in the shale at two localities. It is much smaller than the representatives of the species figured by Hall, ranging from 2½ to 8 millimeters in length.

Distribution.—Bells Valley, Va., and Ridgeville, W. Va.

PELECYPODA.

Genus GRAMMYSIA De Verneuil.

GRAMMYSIA sp.

This genus is represented by a single specimen showing only the anterior portion of a right valve. It represents a species of the same general type as *G. subarcuata*.

Distribution.—Cumberland, Md.

Genus PALÆONEILO Hall.

PALÆONEILO cf. CONSTRICTA (Conrad).

Plate VII, figure 10.

1842. Cf. *Nuculites constricta.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 249, pl. 15, fig. 8.
1843. *Nucula bellatula.* Hall, Nat. Hist. New York, Geology, vol. 4, 1843, p. 196, text fig. 7, p. 197, table illust. 40, fig. 7.
1847. *Nucula bellatula.* Owen (Hall), Am. Jour. Sci., 2d ser., vol. 3, 1847, p. 62, fig. 7, in text.
1857. *Nucula bellatula.* Billings, Canadian Nat. Geology, vol. 1, 1857, p. 473, pl. opp. p. 400, fig. 6.
1861. *Nucula bellatula.* Lincklaen, Fourteenth Rept. New York State Cab. Nat. Hist. (August), 1861, pl. 14, fig. 7.
1869. Cf. *Palæoneilo constricta.* Hall, Prelim. Notice Lamellibr., pt. 2, December, 1869, p. 7.
1882. Cf. *Palæoneilo constricta.* Whitfield, Geology of Wisconsin, vol. 4, 1882, p. 335, pl. 26, figs. 13, 14.
1883. Cf. *Palæoneilo constricta.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 48, figs. 1–15; pl. 51, fig. 17.
1884. Cf. *Palæoneilo constricta.* Hall, [First] Rept. State Geologist New York, 1884, pl. 7, fig. 16.
1885. Cf. *Palæoneilo constricta.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 333, pl. 48, figs. 1–16; pl. 51, fig. 17.
1889. Cf. *Palæoneilo constricta.* Miller, North Am. Geol. and Pal., 1889, p. 499, text fig. 881.
1896. Cf. *Palæoneilo constricta.* Kindle, Bull. Am. Paleontology, vol. 2, 1896, p. 42.
1899. Cf. *Palæoneilo constricta.* Grabau, Bull. Buffalo Soc. Nat. Sci., vol. 6, 1899, p. 256, text fig. 173.
1900. Cf. *Palæoneilo constricta.* Grabau, Sixteenth Rept. State Geologist New York, for 1896, 1900, p. 257.
1903. Cf. *Palæoneilo constricta.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p . 64.
1904. Cf. *Palæoneilo constricta.* Clarke, Mem. New York State Mus. No. 6, 1904, pp. 311, 356, 357, pl. 15, figs. 9–13.
1904. Cf. *Palæoneilo constricta.* Raymond, Annals Carnegie Mus., vol. 3, 1904, p. 169.
1906. Cf. *Palæoneilo constricta.* Grabau, Bull. New York State Mus. No. 92 (Fifty-eighth Ann. Rept., vol. 3, for 1904), 1906, p. 330.
1906. *Palæoneilo constricta.* Slocom, Field Columbian Mus., geol. ser., vol. 2, No. 8, 1906, p. 265.

1908. *Palæoneilo cf. constricta.* Clarke, Mem. New York State Mus. No. 9, 1908, p. 233, pl. 24, fig. 6.

1911. *Palæoneilo constricta.* Cleland, Bull. Wisconsin Geol. and Nat. Hist. Survey No. 21, 1911, p. 102, pl. 20, figs. 9, 19, 20, 21, 22.

A *Palæoneilo* having apparently most of the essential characters of *P. constricta* occurs in the same bed with numerous specimens of *Chonetes mucronatus.* It has the constricted postero-basal margin and fine concentric striæ of that species, but is rather more gibbous in the umbonal region than ordinary examples of *P. constricta.*

Distribution.—Blair County, Pa., and Cumberland, Md.

Genus **BUCHIOLA** Barrande.

BUCHIOLA HALLI Clarke.

1885. *Glyptocardia speciosa* (pars). Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 426, pl. 70, fig. 9 [not figs. 2–8 nor pl. 80, fig. 10].

1904. *Buchiola halli.* Clarke, Mem. New York State Mus. No. 6, 1904, pp. 301–302, pl. 10, figs. 15, 16.

Clarke has separated under the name *Buchiola halli* a Marcellus species which Hall originally included under the same name with the Portage species *Glyptocardia speciosa.*[1] The two forms are quite distinct and with the larger Marcellus species I have identified several specimens showing the strong nodose ribs and large size characterizing *B. halli.* The smaller species (*Buchiola speciosa*) occurs at the Portage horizon in most of the sections but has not been observed in the Onondaga.

Distribution.—Sassin, Va.

Genus **NUCULA** Lamarck.

NUCULA cf. CORBULIFORMIS Hall.

Plate VII, figure 15.

1869. Cf. *Nucula corbuliformis.* Hall, Prelim. Notice Lamellibr., pt. 2, December, 1869, p. 2.

1883. Cf. *Nucula corbuliformis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 46, figs. 24–37.

1885. Cf. *Nucula corbuliformis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 319, pl. 46, figs. [10, 11]? 24–34 [35–37]?.

1889. Cf. *Nucula corbuliformis.* Lesley, Geol. Survey Pennsylvania, Rept. P4, 1889, p. 469, 3 text figs.

1896. Cf. *Nucula corbuliformis.* Kindle, Bull. Am. Paleontology, vol. 2, 1896, p. 42.

1899. Cf. *Nucula corbuliformis.* Grabau, Bull. Buffalo Soc. Nat. Sci., 1899, p. 253, text fig. 169A.

1901. Cf. *Nucula corbuliformis?.* Kindle, Twenty-fifth Ann. Rept. Indiana Dept. Geol. Nat. Res., 1901, p. 677, pl. 14, fig. 5.

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[1] Paleontology of New York, vol. 5, pt. 1, pl. 70, fig. 9; pl. 80, fig. 10.

1903. Cf. *Nucula corbuliformis.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p. 63.
1904. Cf. *Nucula corbuliformis.* Raymond, Annals Carnegie Mus., vol. 3, 1904, p. 169.

Three or four small Nuculas found in the collection are closely allied to, if not identical with, *N. corbuliformis.* The figured specimen is somewhat flattened by pressure. In general outline and in the fine close concentric striæ it does not appear to differ materially from the New York examples of *N. corbuliformis.*

Distribution.—McVeytown, Pa.; Berkeley Springs, W. Va.; and Bells Valley, Va.

Genus NUCULITES Conrad.

NUCULITES MODULATUS n. sp.

Plate VII, figures 13, 14.

Shell elongate ovate, length usually about two-thirds the width. Cardinal line nearly straight or slightly arcuate. Basal margin regularly arcuate, anterior and posterior margins broadly rounded. A nearly vertical clavicle extends from the hinge line just anterior to the beaks two-thirds the distance to the basal margin.

Valves moderately convex in the umbonal region, less convex in the lower and posterior portions. Beaks anteriorly placed, appressed and not rising above the hinge line. Umbonal slope undefined and broadly rounded, blending with the depressed posterior border. Transverse teeth slightly arched, with the crest toward the beaks. Surface marked by fine concentric striæ. Three specimens measure 7, 8, and 8 millimeters in height and 11, 14, and 13 millimeters in length. This species is rather closely allied to *Nuculites oblongus* from the Hamilton. It is distinguished from this shell, however, by the greater proportional width, the broader, more regularly rounded, posterior margin, and the less pronounced umbonal slope.

Distribution.—McVeytown, Pa.; Cumberland, Md.; Ridgeville, W. Va.; Bells Valley, Va.

Genus LUNULICARDIUM Munster.

LUNULICARDIUM CURTUM Hall.

Plate VII, figure 16.

1870. *Lunulicardium curtum.* Hall, Prelim. Notice Lamellibr., pt. 2, 1870, p. 97.
1883. *Lunulicardium curtum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 71, figs. 12–23.
1884. *Lunulicardium curtum.* Hall, [First] Rept. State Geologist New York, 1884, pl. 10, fig. 1.
1885. *Lunulicardium curtum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 437, pl. 71, figs. 18–23.
1889. *Lunulicardium curtum.* Miller, North Am. Geol. and Pal., 1889, p. 486, text fig. 841.

1899. *Lunulicardium curtum.* Grabau, Bull. Buffalo Soc. Nat. Sci., vol. 6, 1899, p. 264, text fig. 185.
1903. *Lunulicardium curtum* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p. 66.
1903. *Lunulicardium curtum.* Wilson, Proc. Onondaga Acad. Sci., Syracuse, vol. 1, 1903, p. 85.

The single specimen referred to this species is a mold which shows the plications and surface striæ imperfectly. The features that are clearly shown are an ovate-subtrigonal outline with anterior and basal margins regularly curving. Entire posterior side truncate with narrow alate margin. Valves moderately convex. Beaks prominent, incurved, and directed forward. Surface marked by about 25 plications.

Distribution.—Occurs in dark shale associated with *Anoplotheca acutiplicata* at Ridgeville, W. Va.

Genus PTEROCHÆNIA Clarke.

PTEROCHÆNIA FRAGILIS (Hall.)

Plate VII, figures 8, 9.

1843. *Avicula fragilis.* Hall, Nat. Hist. New York, Geology, vol. 4, 1843, p. 222, text figs. 1, 2; table illus. 51, figs. 1, 2.
1847. *Avicula fragilis.* Owen (Vanuxem), Am. Jour. Sci., 2d ser., vol. 3, 1847, p. 165, figs. 1, 2, in text.
1860. *Avicula fragilis.* Emmons, Man. Geology, 1860, p. 148, text fig. 2.
1861. *Avicula fragilis.* Lincklæn, Fourteenth Rept. New York State Cab. Nat. Hist. (August), 1861, pl. 16, figs. 16, 18.
1877. *Aviculopecten fragilis.* S. A. Miller, Cat. North Am. Pal. Fos., 1877, p. 184.
1883. *Lunulicardium fragile.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 71, figs. 1–14.
1884. *Lunulicardium fragile.* Hall, [First] Rept. State Geologist New York, 1884, pl. 10, fig. 3.
1885. *Lunulicardium fragile.* Clarke, Bull. U. S. Geol. Survey No. 16, 1885, p. 23.
1885. *Lunulicardium fragile.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 434, pl. 71, figs. 1–14.
1885. *Lunulicardium fragile.* Clarke, Bull. U. S. Geol. Survey No. 16, 1885, p. 62.
1887. *Lunulicardium fragile.* Williams, Bull. U. S. Geol. Survey No. 41, 1887, p. 38, pl. 3, fig. 7.
1889. Cf. *Lunulicardium fragile.* Lesley, Geol. Survey Pennsylvania, Rept. P4, 1889, p. 363. (Left-hand text figure only.) Also vol. 2, p. I.
1899. *Lunulicardium fragile.* Grabau, Bull. Buffalo Soc. Nat. Sci., vol. 6, 1899, p. 263, text fig. 183.
1900. *Lunulicardium fragile.* Grabau, Sixteenth Rept. State Geologist New York, for 1896, 1900, p. 259.
1901. *Lunulicardium fragile.* Kindle, Twenty-fifth Ann. Rept. Indiana Dept. Geol. Nat. Res., 1901, p. 575.
1902. *Lunulicardium fragile.* Wood, Bull. New York State Mus. No. 49, 1901, p. 168, pl. 9, figs. 18, 19.
1903. *Lunulicardium fragile.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p. 66.
1904. *Pterochænia fragilis.* Clarke, Mem. New York State Mus. No. 6, 1904, p. 249, pl. 5, figs. 1–10.
1906. *Pterochænia fragilis.* Kindle, Jour. Geology, vol. 14, No. 7, 1906, p. 633.

This species has been observed at but one locality, where it occurs abundantly. The specimens all appear to belong to the "broadly spatulate or elongate form"[1] which Clarke considers the normal and usual expression of the species. The shells show some variability in the surface markings. The lines of growth give a distinctly lamellose appearance to the surface of some specimens which is not seen in others. Fine radiating striæ have been observed on the surface of but one specimen. An average specimen has a length and height of 5 millimeters. A larger fragmentary specimen shows a height of 15 millimeters.

Distribution.—Occurs in dark shale at Sassin, Va.

Genus **PTERINEA** Goldfuss.

PTERINEA sp. undet.

Plate VIII, figure 4.

The collection from southwestern Virginia includes two left valves of an undetermined *Pterinea.* The best-preserved specimen, which is figured, though nearly flat, snows evidence of having been moderately convex in the crumpled fracture line resulting from pressure. The shell is large and erect; height and length nearly equal; margin regularly curved. Hinge line straight, equal to or greater than the greatest length of the shell. Beak anterior; ear small, limited by a distinct sulcus; wing broad and rather sharply delimited from the rest of shell. Surface of the valve marked by strong elevated radii which are separated by wide flat interspaces. These show a slight posterior curvature in the upper portion of their course. The ear and wing are marked by radii of much less strength than the body of the valve, but the entire surface is cancellated by concentric striæ of equal strength, which are rather widely spaced. In outline and general appearance this shell is comparable with *P. consimilis* of the Chemung. The radii of *P. consimilis,* however, are flattened and those of this species are rounded.

Distribution.—Little Moccasin Gap, Va.

Genus **CONOCARDIUM** Bronn.

CONOCARDIUM cf. CUNEUS var. NASUTUM.

1883. Cf. *Conocardium nasutum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 67, figs. 12-20.

1885. Cf. *Conocardium cuneus* var. *nasutum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 410, pl. 67, figs. 12-20.

1901. Cf. *Conocardium cuneus* var. *nasutus.* Kindle, Twenty-fifth Ann. Rept. Indiana Dept. Geol. Nat. Res., 1901, p. 688.

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[1] Mem. New York State Mus. No. 6, p. 249.

The collections from Pennsylvania and Virginia contain two poorly preserved specimens of a small *Conocardium*. They appear, so far as can be judged from the character of the material, to represent this species.

Distribution.—New Bloomfield, Pa., and Little Moccasin Gap, Va.

Genus **ACTINOPTERIA** Hall.

ACTINOPTERIA MURICATA Hall.

Plate VIII, figure 6.

1843. *Avicula muricata.* Hall, Nat. Hist. New York, Geology, vol. 4, 1843, p. 180, text fig. 5; p. 181; table illus. 39, fig. 5.

1847. *Avicula muricata.* Owen (Hall), Am. Jour. Sci., 2d ser., vol. 3, 1847, p. 59, fig. 5, in text.

1883. *Actinopteria muricata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 17, figs. 1–3.

1884. *Actinopteria muricata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 1, 1884, p. 108, pl. 17, figs. 1–3.

1884. *Actinopteria muricata,* Hall, Thirty-fifth Rept. New York State Mus. Nat. Hist., 1884, p. 297.

1884. *Actinopteria muricata.* Hall, [First] Rept. State Geologist New York, 1884, pl. 3, fig. 14.

1884. *Actinopteria muricata.* Hall, Prelim. Notice Lamellibr., pt. 1, 1884, pl. 3, fig. 14.

1885. *Actinopteria muricata.* Hall, Nat. Hist. New York, Paleontology, vol 5, pt. 1, 1885, p. 108, pl. 17, figs. 1–3.

1902. *Actinopteria muricata.* Wood, Bull. New York State Mus. No. 49, 1901 (1902), p. 168.

Shell small, oblique, and strongly auriculate. Wing triangular, flat, and mucronate. It is delimited from the body of the shell by a nearly straight line extending from the beak to the posterior margin. A shallow sulcus and broad low fold extending from the beak separates the triangular ear from the rest of the shell. A specimen of average size has a height of 6½ and a length of 8 millimeters. Test covered by 12 to 18 prominent elevated striæ, widely spaced. These terminate in short spines at the margin, which are seldom preserved. Very fine radiating striæ may be observed between these on well-preserved shells. The surface is cancellated by concentric striæ, which, together with the radiating striæ, cover the wing.

Distribution.—Occurs in soft drab shales associated with one or two other aviculoid shells in Blair County, Pa.; Ridgeville, W. Va.; and Clifton Forge, Va.

Genus AVICULOPECTEN McCoy.

AVICULOPECTEN EQUILATERA (Hall).

Plate VIII, figures 2, 3.

1843. *Avicula equilatera.* Hall, Nat. Hist. New York, Geology, vol. 4, 1843, p. 180, text fig. 7; p. 181; table illus. 39, fig. 7.
1847. *Avicula equilatera.* Owen (Hall), Am. Jour. Sci., 2d ser., vol. 3, 1847, p. 59, fig. 7, in text.
1859. *Aviculopecten equilatera.* Hall, Twelfth Rept. New York State Cab. Nat. Hist., 1859, p. 89.
1861. *Avicula equilatera.* Linceklæn, Fourteenth Rept. New York State Cab. Nat. Hist. (August), 1861, pl. 12, fig. 7.
1889. *Aviculopecten equilaterus.* Lesley, Geol. Survey Pennsylvania, Rept. P4, 1889, p. 74, 1 text fig.
1891. *Aviculopecten? equilatera.* Whitfield, Annals New York Acad. Sci., vol. 5, 1891, p. 551, pl. 11, fig. 16.
1893. *Aviculopecten? equilatera.* [May=*A. invalidus*] Whitfield, Geol. Survey Ohio, Paleontology, vol. 7, 1893, p. 445, pl. 7, fig. 16.

Shell small and slightly oblique, depressed convex. Hinge line straight, equal to greatest length of shell. Beak nearly central on hinge line. Anterior cardinal angle apparently mucronate; margin of shell below the cardinal line slightly sinuate and gently rounded to the posterior margin, which is nearly straight but is directed slightly backward in descending from the hinge line to the rounded posterior margin. Surface covered with 15 to 20 strong rounded plications, which are crossed by finer concentric undulations.

The species is represented by two left valves which appear to be identical with the Marcellus species described by Hall.

Distribution.—Ridgeville, W. Va., and Blair County, Pa.

Genus MODIOMORPHA Hall.

MODIOMORPHA SUBALATA (Conrad).

Plate VIII, figure 1.

1841. *Cypricardites subalata.* Conrad, Fifth Ann. Rept. New York Geol. Survey, 1841, p. 53.
1869. *Modiomorpha subalata.* Hall, Prelim. Notice Lamellibr., pt. 2, December, 1869, p. 77.
1883. *Modiomorpha subalata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 39, figs. 1–16; pl. 41, figs. 5–9.
1884. *Modiomorpha subalata.* Hall, [First] Rept. State Geologist New York, 1884, pl. 6, fig. 10.
1885. *Modiomorpha subalata.* Hall. Nat. Hist, New York, Paleontology, vol. 5, pt. 1, Lamellibr. 2, 1885, p. 283, pl. 35, figs. 6, 7; pl. 39, figs. 1–14, 16.
1889. *Modiomorpha subalata.* Lesley, Geol. Survey Pennsylvania, Rept. P4, 1889, p. 416, 1 text fig.
1896. *Modiomorpha subalata.* Kindle, Bull. Am. Paleontology, vol. 2, 1896, p. 43.
1899. *Modiomorpha subalata.* Grabau, Bull. Buffalo Soc. Nat. Sci., 6, 1899, p. 250, text fig. 166.
1900. *Modiomorpha subalata.* Grabau, Sixteenth Rept. State Geologist New York for 1896, 1900, p. 254.

1903. *Modiomorpha subalata.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p. 70.
1906. *Modiomorpha subalata.* Grabau, Bull. New York State Mus., No. 92 (Fifty-eighth Ann. Rept., vol. 3 for 1904), 1906, p. 330.
1909. *Modiomorpha subalata.* Stauffer, Bull. Ohio Geol. Survey, 4th ser., No. 10, 1909, p. 165.

The collection contains but one specimen of this species—a right valve. Its salient features are as follows: Beak anteriorly placed; basal margin nearly straight; cardinal margin sloping upward slightly from the beak. The specimen has been broken by pressure near the middle and bent downward posteriorly. Posterior margin obliquely truncate. A strong, angular, umbonal ridge extends from the beak to the posterior basal border. Surface marked by fine concentric striæ and some lamellose lines of growth.

Distribution.—In tough dark-drab shale at Cumberland, Md.

Genus CYPRICARDINIA Hall.

CYPRICARDINIA INDENTA (Conrad).

Plate VII, figures 11, 12.

1842. *Cypricardites indenta.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 244, pl. 12, fig. 12.
1870. *Cypricardinia indenta.* Hall, Prelim. Notice Lamellibr., pt. 2, January, 1870, p. 83.
1883. *Cypricardinia indenta.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 79, figs. 6–23.
1884. *Cypricardinia indenta.* Hall, [First] Rept. State Geologist New York, 1884, pl. 11, figs. 11, 12.
1884. *Cypricardinia indenta.* Walcott, Mon. U. S. Geol. Survey, vol. 8, 1884, p. 182, pl. 5, fig. 14; pl. 15, fig. 11.
1885. *Cypricardinia indenta.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 485, pl. 79, figs. 6–16, 23; pl. 96, fig. 2.
1889. *Cypricardinia indenta.* Lesley, Geol. Survey Pennsylvania, Rept. P4, 1889, p. 176, 1 text fig.
1892. *Cypricardinia* cf. *lamellosa.* Clarke, Am. Jour. Sci., 3d ser., vol. 44, 1892, p. 413.
1899. *Cypricardinia indenta.* Grabau, Bull. Buffalo Soc. Nat. Sci., vol. 6, 1899, p. 268, text fig. 191.
1900. *Cypricardinia indenta.* Grabau, Sixteenth Rept. State Geologist New York, for 1896, 1900, p. 260.
1900. *Cypricardinia indenta.* Clarke, Mem. New York State Mus., vol. 3, No. 3, 1900, p. 36, pl. 4, figs. 18–20.
1901. *Cypricardinia indenta.* Kindle, Twenty-fifth Ann. Rept. Indiana Dept. Geol. Nat. Res., 1901, p. 685, pl. 15, figs. 8, 8a.
1902. *Cypricardinia indenta.* Wood, Bull. New York State Mus. No. 49, 1901 (1902), p. 168.
1903. *Cypricardinia indenta.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p.72.
1904. *Cypricardinia indenta.* Raymond, Annals Carnegie Mus., vol. 3, 1904, p. 171.
1908. *Cypricardinia indenta.* Kindle, Bull. Geol. Soc. America, vol. 19, 1908, p. 328.
1909. *Cypricardinia indenta?* Stauffer, Bull. Ohio Geol. Survey, 4th ser., No. 10, 1909, p. 165.
1911. *Cypricardinia* cf. *indenta.* Cleland, Bull. Wisconsin Geol. and Nat. Hist. Survey No. 21, 1911, p. 117, pl. 26, fig. 3.

This shell is described by Hall[1] as follows:

> Shell of medium size, subrhomboid-ovate; length more than one-third greater than the height; basal margin nearly straight, slightly sinuate anterior to the middle. Posterior extremity abruptly rounded below and obliquely truncate above. Cardinal line straight, oblique. Anterior end very short, rounded below. Right valve convex, often extremely gibbous. Left valve usually depressed convex below and posteriorly, becoming moderately gibbous in the umbonal region. Beaks nearly anterior small and appressed, rising but little above the hinge line. Cincture distinct upon the right valve, less marked upon the left valve. Umbonal slope rounded and prominent on right valve, subangular on the left valve. Surface marked by extremely fine concentric striæ, and by unequally distant but somewhat regular, lamellose, imbricating, concentric undulations; and in well-preserved specimens the entire surface is marked by fine striæ which radiate from the apex of the shell, and in some conditions of preservation the surface shows a second set of striæ vertical to the direction of the lamellæ. Four specimens measure, respectively, 11, 14, 18, and 20 millimeters in length and 7, 8, 11, and 11 millimeters in height.

All the shells studied by the writer display prominently the peculiar characteristic criss-cross ornamentation characterizing the strongly lamellose surface, which is mentioned by Hall as an occasional feature of this shell. The sculpturing and the fine concentric lines mentioned by Hall have both been observed on but one specimen. The transverse sculpture is the coarser of the two, and when strongly developed tends to obliterate the very fine concentric striæ. The specimens studied are much smaller than those described by Hall but show no other differences from those of the New York fauna.

Distribution.—Mendota and Little Moccasin Gap, Va.

Genus LEIOPTERIA Hall.

LEIOPTERIA LÆVIS Hall.

Plate VIII, figure 5.

1843. *Avicula lævis.* Hall, Geol. Survey New York, Rept. Fourth District, 1843, p. 181.

1847. *Avicula lævis.* Owen (Hall), Am. Jour. Sci., 2d ser., vol. 3, 1847, p. 59, text fig. 6.

1859. *Pteronites? lævis.* Hall, Twelfth Rept. New York State Cab. Nat. Hist., 1859, p. 89.

1861. *Avicula lævis.* Lincklaen, Fourteenth Rept. New York State Cab. Nat. Hist., 1861, pl. 12, fig. 6.

1883. *Leiopteria lævis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 17, figs. 5–11.

1884. *Leiopteria lævis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 1, 1884, p. 158, pl. 17, figs. 5–11; pl. 20, fig. 5.

1884. *Leiopteria lævis.* Hall, Thirty-fifth Rept. New York State Mus. Nat. Hist., 1884, p. 334.

1889. *Pteronites lævis.* Lesley, Rept. P4, Geol. Survey Pennsylvania, 1889, p. 817, text figs.

1903. *Leiopteria lævis.* Cleland, Bull. U. S. Geol. Survey No. 206, 1903, p. 67.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 1, 1885, p. 485, pl. 79, figs. 6–16, 23; pl. 96, fig. 2.

This species is represented in the collection by a single left valve. Hall[1] described the species as follows:

> Shell small, subrhomboidal; body obliquely ovate; length and height nearly equal; greatest length below the middle; margins regularly rounded, somewhat extended on the postbasal side. Left valve more convex than the right; the greatest convexity in both valves is above the middle. Hinge line straight on the posterior side of the beak, turning abruptly downward in front; entire length greater than the length of the shell. Beaks obtuse, rounded, inclined forward, situated at the anterior third of the shell, that of the left valve quite prominent. Umbonal region of left valve prominent, subtending an acute angle. Ear triangular, nearly equilateral, with a strong angular fold along the middle, separated from the body of the valve by a distinct rounded sulcus and broad byssal sinus; margin rounded; extremity obtuse. Wing triangular, flat, limited by the postumbonal slope; margin concave; extremity acute. Test thin, marked with distinct concentric striæ of growth, which are crowded and conspicuous on the wings. There are often obscure traces of radii, which are more distinct on the wing in casts or exfoliated specimens. Ligamental area narrow, with a single distinct groove. Some specimens apparently indicate the existence of an oblique lateral tooth on the posterior side of the umbo.

The writer's specimen is smaller than those described by Hall, the height of the shell being only 5 millimeters and the length of the hinge line 6 millimeters.

Distribution.—Cumberland, Md.

Genus PANENKA Barrande.

PANENKA cf. DICHOTOMA Hall.

Plate VII, figure 17.

1883. *Cardiola? dichotoma.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr. (adv. copy), 1883, pl. 70, fig. 21.

1885. *Panenka dichotoma.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 416, pl. 70, fig. 21; pl. 94, fig. 13.

1906. *Panenka dichotoma.* Grabau, Bull. New York State Mus. No. 92 (Fifty-eighth Ann. Rept., vol. 3, for 1904), 1906, p. 326.

The collection contains two specimens, which are probably identical with *P. dichotoma,* but owing to some imperfection in the material its identity can not be stated with certainty. Shell broadly ovate in outline, moderately convex in the anterior portion, depressed convex in the posterior portion. Surface marked by about 35 strong narrow radii in the anterior portion which become very broad and flattened in the posterior portion. Some of these on the posterior half of the shell split into three flattened radii near the center margin of the shell. Fine concentric striæ cross the radii.

Distribution.—Ridgeville, Va., and Oldtown, Md.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 1, 1884, pp. 158-159, pl. 17, figs. 5-11; pl. 20, fig. 5.

PANENKA cf. MULTIRADIATA Hall.

1883. *Cardiola radians* (pars). Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1 (adv. copy), 1883, pl. 69, fig. 5 [non figs. 6–11].
1885. *Panenka multiradiata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 417, pl. 69, fig. 5; pl. 94, fig. 18.

The collection contains one specimen which bears considerable resemblance to this species. The beak, however, appears to be much less prominent.

Distribution.—Blair County, Pa.

PANENKA ALTERNATA Hall.

1885. *Panenka alternata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 1, Lamellibr., pt. 2, 1885, p. 416, text fig. p. 562.
1909. *Panenka alternata.* Stauffer, Bull. Ohio Geol. Survey, 4th ser., No. 10, 1909, pp. 166, 181.

This species is represented in the collections by a single specimen having about the same size as the one figured by Hall. It occurs in association with three other specimens of *Panenka* in a dark, slightly calcareous shale.

Distribution.—Oldtown, Md.

GASTROPODA.

Genus PLATYOSTOMA Conrad.

PLATYOSTOMA cf. EUOMPHALOIDES Hall.

1876. Cf. *Platyostoma euomphaloides.* Hall, Illus. Dev. Foss., 1876, pl. 9.
1879. Cf. *Platyostoma euomphaloides.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 25, pl. 10, figs. 27–29.

A crushed specimen bearing considerable resemblance to this species occurs in the collection.

Distribution.—Cumberland, Md.

PLATYOSTOMA TURBINATA Hall.

Plate VIII, figure 12.

1861. *Platyostoma turbinata.* Hall, Fourteenth Rept. New York State Cab. Nat. Hist., 1861, p. 106.
1879. *Platyostoma turbinata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 27, pl. 9, figs. 12–24.

This species is represented by four specimens, all from a single locality, where it is rather common in one of the thin bands of dark limestone. The specimen figured is the largest of the four as well as the most completely exfoliated. These specimens represent the type of the shell with elevated spire. The surface is marked by fine transverse striæ which make an abrupt retral bend on the periphery of the last volution. No revolving striæ are preserved except a fine, threadlike line marking the retral angle of the transverse striæ on the periphery of the outer volution. Hall[1] has described this species as follows in part:

> Shell, subturbinate, sometimes approaching a subglobose form. Spire depressed, or more or less elevated above the outer volution, sometimes nearly on the same plane; volutions three or four, rapidly expanding, the last extremely ventricose, with the lower part projected in the direction of the columella, which is much extended. Aperture subovate, broader above, narrowing and often extended below. Surface marked by fine subequal concentric striæ, crossed by fine revolving striæ; the former variously undulated upon the surface, indicating sinuosities in the aperture at different stages of growth. In older shells the striæ become lamellose and often crowded in fascicles.

Distribution.—McVeytown, Pa.

PLATYOSTOMA LINEATA Hall.

1842. *Platyostoma lineata.* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 276, pl. 17, fig. 7.

1879. *Platyostoma lineata.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 21, pl. 10, figs. 1-21.

This species is represented by a small partly exfoliated shell 6 millimeters in diameter. It has been described by Hall[2] as follows:

> Shell subovate, approaching to subglobose. Spire elevated above the body whorl, though varying in degree; in some extreme varieties, on the same plane or below the outer volution.
>
> The shell with four or five volutions when entire, but seldom preserving more than three, the apex being usually imperfect, the outer volution usually very ventricose and regularly convex, a little depressed below the suture line (but not caniculate). Aperture suborbicular in perfect specimens, sometimes subrhomboidal outer lip thin, with sharp entire margin; columellar lip thickened, folded, and reflexed over the umbilicus, which in adult specimens is entirely closed.
>
> Surface marked by fine, equidistant threadlike revolving striæ, which are cancellated by fine concentric striæ of about the same strength, but unequally distant; the latter sometimes bend abruptly backward upon the back of the shell, indicating a sinus in the lip at some period of growth and are frequently crowded in fascicles, giving a rugose character to the surface.

Distribution.—Blair County, Pa.

Genus NATICOPSIS McCoy.

NATICOPSIS sp. undet.

Plate VIII, figure 11.

Casts of a small species of *Naticopsis* of undetermined identity occur in the dark shale at some localities.

Distribution.—Blair County, Pa.; Ridgeville, W. Va.; and Cumberland, Md.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 2, 1879, p. 27.

[2] Idem, p. 21.

Genus PLATYCERAS Conrad.

PLATYCERAS THETIS Hall.

Plate VIII, figure 13.

1862. *Platyceras thetis.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 32.
1879. *Platyceras thetis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 8, pl. 3, figs. 11-16.

This species is represented in the collection by a single specimen, which is here figured. The erect portion of the shell has been distorted and flattened by pressure. The description of the species, as given by Hall,[1] is as follows:

> Shell obliquely arcuate from the base, with the apex incurved, the nucleus making barely more than a single minute volution; gradually expanding from the apex to near the aperture, which is sometimes more abruptly spreading. The back of the body whorl is prominent, and a little flattened on the left side, while the right side from one-third to one-half the length is sometimes marked by two or three longitudinal folds, and often by more numerous, finer plications. Aperture a little oblique, nearly round or subquadrangular, with the peristome sinuous.
>
> Surface marked by fine, closely arranged lamellose striæ, which are abruptly undulated on all parts of the body of the shell. In many, and perhaps nearly all, specimens the body of the shell along a line a little to the left of the dorsum is marked by an abrupt curvature of the striæ, indicating a notch in the margin of the peristome. This line is sometimes marked by a narrow prominent band not unlike that of *Pleurotomaria.*

Distribution.—New Bloomfield, Pa.

PLATYCERAS cf. RICTUM Hall.

1862. Cf. *Platyceras rictum.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 35.
1879. Cf. *Platyceras rictum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 13, pl. 4, figs. 6, 12-17.

A small depressed shell, which may be a young specimen of this species, is found in one of the collections. The nucleus is very small, outer whorl abrupt and broadly expanded. Surface marked by fine transverse undulating striæ.

Distribution.—Schuylkill Haven, Pa.

PLATYCERAS sp. undet.

The collection includes a third species of *Platyceras*, represented by fragmentary material. The shell is strongly arcuate with regular transverse striæ; aperture 16 millimeters in diameter.

Distribution.—Clifton Forge, Va.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 2, 1879, p. 8.

Genus **LOXONEMA** Phillips.

LOXONEMA HAMILTONIÆ Hall.

Plate VIII, figures 9–10.

1862. *Loxonema hamiltoniæ*. Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 53.
1879. *Loxonema Hamiltoniæ*. Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 45, pl. 13, figs. 15, 17.

This species has been described by Hall[1] as follows:

> Shell elongate, subulate. Volutions moderately convex, about thirteen in the largest specimens known, very gradually increasing in size from the minute apex, the last one ventricose. Aperture ovate, narrowing below; columella extended. Surface marked by longitudinal, sharp, curving striæ, which bend gently backward from the suture, and forwards toward the base of the volution, having the greatest curve near the middle, those of the last volution curving abruptly backward to the columellar lip. Striæ separated by distinctly defined grooves which are a little wider than the ridges; the striæ increasing in distance as the shell grows older.

The specimens in the collection are all preserved in soft shales and somewhat flattened. The largest specimen observed has fourteen volutions and a length of nearly 2 inches. Average specimens have from 10 to 13 volutions.

Distribution.—Blair County, Pa.; Cumberland, Md.; Ridgeville, W. Va.

LOXONEMA cf. PEXATA Hall.

1861. Cf. *Loxonema pexata*. Hall, Fourteenth Rept. New York State Cab. Nat. Hist., 1861, p. 104.
1879. Cf. *Loxonema pexata*. Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 42, pl. 13, figs. 16, 18 (11, 12)?

The loxonemas from one of the localities are all smaller, less elongate, and with less than half the volutions seen in *L. hamiltoniæ*. The specimens probably represent *L. pexata*. The species has been described by Hall[2] as follows:

> Shell elongate, terete or subfusiform. Volutions six or more, gradually expanding from the apex, somewhat flattened on the upper half, or a little concave just below the suture, and most convex below the middle; the last one moderately ventricose. Aperture subelliptical. Surface marked by strong, regular, elevated striæ, which cross the volutions in a gentle curve, turning backward from the suture and again forward, making the curve at about one-third of the distance from the upper side of the volution. On well-preserved specimens the striæ are sharply elevated, but are subject to considerable variation, which may be due to erosion or maceration before embedding.

Distribution.—Blair County, Pa., 2 miles west of Canal Creek.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 2, 1879, p. 45.
[2] Idem, pp. 42–43.

Genus BELLEROPHON Montfort.

BELLEROPHON sp. undet.

One of the specimens in the collection exhibits features of surface sculpture which I have not been able to identify with any described species, although it may represent a variety of *Bellerophon leda*. Surface marked by fine revolving striæ, 12 or more to a millimeter. Dorsal band without any elevation, with traces of indistinct revolving striæ limited by two threadlike striæ similar to the other revolving striæ on either side. Surface marked by lines of growth which make a strong retral curve in crossing the dorsal band.

Distribution.—Blair County, Pa.

BELLLEROPHON LEDA Hall.

Plate VIII, figure 14.

1862. *Bellerophon leda.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 58.

1879. *Bellerophon leda.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 110, pl. 23, figs. 2-16.

The few specimens of this species which have been observed are all much smaller than those figured by Hall. They are too fragmentary to show much more than the characteristic surface markings of the species. These include strong revolving striæ cancellated by nearly equally strong transverse striæ; a narrow concave and moderately elevated dorsal band. In crossing this the transverse striæ make an abrupt retral curve.

The following description of the species is drawn from Hall.[1]

> Shell subglobose, often a little flattened upon the dorsum; body whorl ventricose, very rapidly expanding. Aperture abruptly spreading, broadly sinuate in front and sometimes with a deeper notch in the middle, the margin gently recurved, joining the volution a little on the ventral side, where it is thickened, somewhat abruptly curving over and partially inclosing the small umbilicus, and extends in a callus over the columellar lip, which is sometimes distinctly striato-pustulose.
>
> Surface marked by strong longitudinal or revolving striæ, which alternate in size, are sometimes fasciculate, and often finer and more numerous on each side of the dorsal band than on the lateral portions of the shell. The revolving striæ are cancellated by finer, subequal, threadlike transverse striæ. The dorsal band is narrow, rarely elevated or sometimes scarcely raised above the surface, and usually flat or slightly concave, the concentric striæ making an abrupt retral curve upon it in crossing. The band is likewise usually marked by one, two, three, or more revolving striæ finer than those on the sides of the shell, and sometimes quite obscure.

Distribution.—Schuylkill Haven, Pa., and Bells Valley, Va.

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[1] Natural history of New York, Paleontology, vol. 5, pt. 2, 1879, p. 110.

BELLEROPHON PELOPS Hall.

1862. *Bellerophon (Bucania) pelops.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 56.

1879. *Bellerophon pelops.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 95, pl. 22, figs. 7–13.

In the collection this shell is represented only by casts of the interior and fragments of the exterior markings. The latter are too fragmentary for figuring, but clearly indicate this species by their correspondence to Hall's figures and original description, which follows.

> Casts of this species occur in the limestone of the Upper Helderberg group.
>
> The shell has been very rotund: the volutions, which have been three or four, were exposed in the umbilicus; the transverse diameter of the volution is about twice as great as the length or dorso-ventral diameter, rounded on the back, and abruptly bent into the umbilicus; the aperture expands laterally, and is somewhat reniform, with a sinus on the dorsal side; the back is distinctly carinate on the last volution, and the surface has apparently been marked by transverse striæ.
>
> It is impossible to characterize the species fully from the materials possessed, but it may be distinguished by its similarity of form to *B. expansus*; but the dorsal carina on the crest of this one is more sharply marked, the volutions are less compressed in the dorso-ventral direction, and the umbilicus is more abruptly depressed.

Distribution.—Blair County, Pa.

Genus PLEUROTOMARIA De France.

PLEUROTOMARIA cf. TRILIX Hall.

1862. Cf. *Pleurotomaria trilix.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 45, pl. 5, fig. 1.

1879. Cf. *Pleurotomaria trilix.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 79, pl. 21, figs. 13–15.

Fragmentary and crushed material representing a single specimen bears some resemblance to this species. It is too incomplete, however, to be more than suggestive of the identity of the form represented.

Distribution.—Clifton Forge, Va.

PLEUROTOMARIA CRASSA n. sp.

Plate VIII, figures 7, 8.

The description of this species is of a single, somewhat fragmentary specimen which, however, shows in its surface sculpturing very distinctive specific characters.

Shell turbinate; spire erect, apparently higher than wide. Volutions about four, subangular on the periphery.

Surface marked by a revolving carina above and below the peripheral band on the second volution. Strong angular transverse striæ separated by spaces equal to twice their width cross these, making nodelike crenulations. These transverse lines swing sharply backward away from the aperture in approaching the slit band. The first volution has one revolving carina above the slit band and two below it. The two lower ones are placed near together, resembling a second peripheral band. The transverse lines in approaching these from the umbilicus are directed anteriorly, but cross them nearly at right angles, then swing backward to the peripheral band.

This shell resembles *P. sulcomarginata* in its strong, coarse sculpturing, but is distinguished from that species by having two carina instead of one below the peripheral band of the first volution.

Distribution.—Blair County, Pa., 2 miles west of Canoe Creek.

PTEROPODA.

Genus STYLIOLINA Karpinsky.

STYLIOLINA FISSURELLA Hall.

1843. *Tentaculites fissurella.* Hall, Geology New York, Survey Fourth Geol. Dist., 1843, p. 180, figs. 9, 10; p. 222, fig. 4.

1879. *Styliola fissurella.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 178, pl. 31A, figs. 1–30.

These minute shells occur in great abundance in dark or drab shales at a few localities. Their average length is about 3 millimeters.

Distribution.—Blair County, Pa.; Cumberland, Md.; Sassin and Bells Valley, Va.

Genus TENTACULITES Schlotheim.

TENTACULITES GRACILISTRIATUS Hall.

Plate IX, figure 4.

1879. *Tentaculites gracilistriatus.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 173, pl. 31, figs. 12, 13; pl. 31A, figs. 37–47.

This shell occurs in about the same abundance as the preceding and is associated with it. It is distinguished from *Styliolina fissurella* by its annulated and longitudinally striated surface.

Distribution.—Same as the preceding species.

TENTACULITES SCALARIFORMIS Hall.

Plate IX, figure 5.

1876. *Tentaculites scalariformis.* Hall, Illus. Dev. Foss., 1876, pl. 26, figs. 3–11.

1879. *Tentaculites scalariformis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 167, pl. 31, figs. 3–11.

This specimen is represented in the collection by a single fragmentary individual. It is of the type represented in figures 3, 5, and 11 by Hall,[1] suggesting a series of minute nested cups with projecting rims. The posterior slope of the annulations is abrupt, and the anterior slope is more gentle. Four or five very fine transverse striæ mark the interval between each pair of annulations. The description of the species as given by Hall is as follows:

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[1] Natural history of New York, Paleontology, vol. 5, pt. 2, 1879, pl. 31.

> Form elongate conical, straight, somewhat more cylindrical in approaching the aperture; with the apex in well-preserved specimens extremely attenuate and quite solid from one-fourth to one-third the entire length of the shell. Annulations prominent, subangular, sometimes rounded on the larger part of the cone, closely arranged and sharply angular near the apex, gradually increasing their distance, becoming less angular with the increase in the size of the shell, and obtuse and rounded toward the aperture; usually but little variation in character on the outer half of the length, where the spaces between are greater than the annulations. Interspaces and annulations, when well preserved, marked by fine, even transverse striæ, of which 9 or 10 may be counted in the furrows, and half as many on the summit and sides of the annulations.

Distribution.—Mendota, Va.

TENTACULITES cf. BELLULUS Hall.

1876. Cf. *Tentaculites bellulus.* Hall, Illus. Dev. Foss., 1876, pl. 26, figs. 15–18.
1879. Cf. *Tentaculites bellulus.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 169, pl. 31, figs. 15–18; pl. 31A, figs. 48–51.

A few fragmentary specimens appear to represent this species. They show very prominent angular annulations of symmetrical type. Fifteen to twenty fine transverse striæ mark the angular interspace between each pair of these, extending up their sides nearly to their crests.

Distribution.—Schuylkill Haven, Pa.

Genus BACTRITES G. Sandberger.

BACTRITES ACICULUM Hall.

Plate IX, figure 3.

1843. *Orthoceras aciculum.* Hall, Geology of New York, Survey Fourth Geol. Dist., 1843, p. 243.
1879. *Coleolus aciculum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 187, pl. 32A, figs. 11–15 (16?).

This fossil occurs on the surface of slabs of dark or drab shale as flattened acicular cones destitute of surface markings.

Distribution.—Cumberland, Md.; Hollidaysburg, Pa.; and Sassin, Va.

BACTRITES cf. TENUICINCTUM Hall.

1876. Cf. *Coleoprion tenuicinctum.* Hall, Illus. Dev. Foss., 1876, pl. 27, figs. 1–4.
1879. Cf. *Coleolus tenuicinctum.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 185, pl. 32, figs. 5–9; pl. 32A, figs. 6–10.

A single small fragmentary specimen appears to be referable to this species.

Distribution.—Mendota, Va.

Genus COLEOLUS Hall.

COLEOLUS? CURVATUS n. sp.

Plate IX, figures 1, 2.

Shell small, tubular, tapering regularly to the acicular extremity. Gently and regularly curved; surface smooth. Average specimen has a length of 10 millimeters and a diameter at the aperture of 1½ millimeters. This shell is closely allied to *Coleolus gracilis* but is rather more strongly curved and tapers more rapidly. *Coleolus gracilis* is also supposed to be transversely striate, while this species is smooth.

This small *Dentalium*-like shell has been observed at but one locality, where it is abundant in a soft drab shale.

Distribution.—Blair County, Pa., in road 2 miles west of Canoe Creek.

Genus HYOLITHES Eichwald.

HYOLITHES cf. ACLIS Hall.

1876. Cf. *Hyolithes aclis.* Hall, Illus. Dev. Foss., 1876, pl. 27, figs. 5, 6, 7, 10, 11.
1879. Cf. *Hyolithes aclis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 197, pl. 32, figs. 22–30; pl. 32A, figs. 23–25.

The collections contain two small specimens in a poor state of preservation which are comparable to this species and may belong to it.

Distribution.—Blair County, Pa., and Ridgeville, W. Va.

HYOLITHES cf. PRINCIPALIS Hall.

1876. Cf. *Hyolithes principalis.* Hall, Illus. Dev. Foss., 1876, pl. 27, figs. 17–20.
1879. Cf. *Hyolithes principalis.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 196, pl. 32, figs. 17–21.

The collections contain a single specimen, which although fragmentary shows marked resemblance to this species. The specimen exhibits rapidly tapering sides and has a maximum breadth of 13 millimeters. Neither the anterior nor the posterior extremities of the shell are preserved.

Distribution.—Occurs in drab shale in Blair County, Pa.

Genus ENCHOSTOMA Miller and Gurley.

ENCHOSTOMA? sp.

The collection contains specimens of a cylindrical rodlike fossil about a millimeter in diameter occurring in an earthy limestone. The specimens represent only fragments rather less than an inch in length, composed of hard chitaneous material. That these have had considerable length is indicated by the barely perceptible amount of tapering seen in the individual specimens. Provisionally they may be referred to *Enchostoma*.

Distribution.—Cumberland, Md.

Genus CONULARIA Miller.

CONULARIA sp. undet.

The collection includes six fragmentary specimens of *Conularia* representing different localities. These are all more or less completely flattened, making specific determination uncertain. One of the specimens at least is comparable and probably identical with *C. undulata*.

Distribution.—Cumberland, Md., and Mountain Grove, Va.

CEPHALOPODA.

Genus ORTHOCERAS Breynius.

ORTHOCERAS cf. SUBULATUM Hall.

1843. Cf. *Orthoceras subulatum*. Hall, Geology of New York, Survey Fourth Geol. Dist., 1843, p. 180, fig. 1.

1879. Cf. *Orthoceras subulatum*. Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 283, pl. 38, fig. 3; pl. 84, figs. 1, 2, 4, 6–10; pl. 86, figs. 1, 2.

The collection contains a few small fragmentary specimens of an *Orthoceras* which, so far as the poor quality of the material permits of study, are comparable with *Orthoceras subulatum*.

Distribution.—Blair County, Pa., and Cumberland, Md.

Genus PARODICERAS Hyatt.

PARODICERAS DISCOIDEUM (Conrad).

1860. *Goniatites discoideus*. Hall, Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 97; figs. 4–6, p. 98.

1879. *Goniatites discoideus*. Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, p. 441, pl. 71. figs. 1–13; pl. 74, figs. 4–5.

This is a rare species, having been recognized at but one locality, where it is represented by fragmentary material. It is possible, moreover, that the faunule with which this species is associated is of Marcellus instead of Onondaga age.

Distribution.—Sassin, Va.

Genus AGONIATITES Meek.

AGONIATITES EXPANSUS (Vanuxem).

Plate IX, figure 6.

1842. *Goniatites expansus.* Vanuxem, Geology of New York, Survey Third Geol. Dist., 1842, p. 146, fig. 1.
1879. *Goniatites vanuxemi.* Hall, Nat. Hist. New York, Paleontology, vol. 5, pt. 2, 1879, pp. 434–438, pls. 66–69, figs. 3–6; pl. 109, figs. 7–8.

This shell occurs in beds near the top of the Onondaga shale. The specimen figured has a maximum breadth of 47 milimeters and represents an individual of average size. The surface is covered with striæ having the direction shown in the figure. The septa are not preserved in the specimens observed. None of these approach in size some of the specimens of *A. expansus* figured by Hall.

Distribution.—Blair County, Pa.; Cumberland and Twenty-first Bridge, Md.

TRILOBITA.

Genus PHACOPS Emmrich.

PHACOPS RANA (Green).

Plate X, figures 1–5.

1832. *Calymene bufo* var. *rana.* Green, Mon. Trilobites North America, 1832, p. 42.
1861. *Phacops rana.* Hall, Desc. New Sp. Fos., 1861, p. 65.
1862. *Phacops rana.* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 93, pl. 10, fig. 12.

This long-ranging species is represented by several specimens, which agree in all essential features with *P. rana* as it appears in the Hamilton. The simple annulations of the pygidium and the absence of genal spines distinguish them from *P. cristata* var. *pipa.* In New York this trilobite ranges more than a thousand feet above the top of the Hamilton; but its presence there in the Onondaga has been reported doubtfully.

Distribution.—Bells Valley, Va., and New Bloomfield, Pa.

PHACOPS CRISTATA Hall.

Plate X, figures 6–8.

1861. *Phacops cristata.* Hall, Desc. New Sp. Fos., 1861, p. 67.
1888. *Phacops cristata.* Hall and Clarke, Nat. Hist. New York, Paleontology, vo.. 7, 1888, p. 14, pl. 6, figs. 1–31, 16–29; pl. 8A, figs. 1–4.

This species and the related form *P. cristata* var. *pipa* are probably the most abundant representatives of the trilobites in this fauna. Although *P. cristata* is readily distinguished from *P. cristata* var. *pipa* by the axial row of spines and other less conspicuous differences in perfect specimens, the two are often difficult to discriminate in the fragmentary material representing them in the average collection. The glabella figured is that of the largest individual observed, having a length and breadth, respectively, of 18 and 24 millimeters. The genal spines, though not shown in the figure, are indicated by broken bases in the specimen.

Distribution.—Schuylkill Haven, Pa.; Alinda and New Bloomfield, Perry County, Pa.; Berkeley Springs and Ridgeville, W. Va.; Clifton Forge, Va.

PHACOPS CRISTATA var. PIPA Hall and Clarke.

Plate X, figures 9, 10.

1888. *Phacops cristata* var. *pipa*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 18, pl. 8A, figs. 5–18.

This species is often not easily distinguished from the preceding. It appears to be represented in the collections by numerous pygidia. It is probably a common species, but the difficulty of distinguishing specimens of this species without nearly perfect material from *P. rana* and *P. cristata* leaves the determination of fragmentary remains doubtful in many instances.

Distribution.—New Bloomfield, Alinda, Hollidaysburg, Pa.; Poplar Hill, Clifton Forge, and Mendota, Va.

Genus CRYPHÆUS Green.

CRYPHÆUS cf. BOOTHI var. CALLITELES (Kayser).

Plate X, figures 14, 15; Plate XI, figure 1.

1878. Cf. *Cryphæus calliteles*?. Kayser, Abhandl. z. Geol. Specialkarte von Pr. u. d. Thur. St., vol. 2, pt. 4, 1878, p. 32, pl. 3, fig. 10.

1888. Cf. *Dalmanites* (*Cryphæus*) *Boothi* var. *Calliteles*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 45, pl. 16, figs. 5–22; pl. 16A, figs. 9–17.

The specimens referred provisionally to this species represent the glabella and a portion of the thorax of five individuals. The pear-shaped glabella varies in length from 4 to 8 millimeters and shows three posterior lateral furrows. A conspicuous tubercle marks the axis of the occipital ring. The best of this fragmentary material is shown in the figures.

Distribution.—Ridgeville, W. Va.; Blair County and New Bloomfield, Pa.

Genus DALMANITES Emmerich.

DALMANITES (CORONURA) ASPECTANS (Conrad)?.

Plate X, figures 12, 13.

1841. Cf. *Asaphus aspectans*. Conrad, Fifth Ann. Rept. Geol. Survey New York, 1841, p. 48, fig. 9.
1888. Cf. *Dalmanites* (*Coronura*) *aspectans*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 33, pl. 13, figs. 1–11, 13.

The specimens here provisionally referred to this species comprise two pygidia, two cephalons, and a detached eye, all from one locality, and one bed of argillaceous limestone. They are too fragmentary to permit certain identification with *D. aspectans*, but the features preserved are so strikingly like those of that species as to leave little doubt of their identity. They show the strongly tuberculose character of the cephalon, the great number of eye facets, and the tubercle-covered pygidium characterizing *D. aspectans*. A portion of the eye is not exposed, but about 250 corneal lenses may be counted on the portion that is visible.

Distribution.—Frankstown, Pa., station 32a.

Genus ODONTOCEPHALUS Conrad.

ODONTOCEPHALUS SELENURUS (Eaton).

Plate XII, figure 6.

1832. *Asaphus selenurus*. Eaton, Geol. Text Book, 1832, p. 31, pl. 1, fig. 1.
1835. *Calymene? odontocephala*. Green, Mon. Trilobites North America, Sup., 1835, p. 9.
1876. *Dalmanites selenurus*. Hall, Illus. Dev. Foss. Crust., 1876, pl. 12, figs. 12–14.
1888. *Dalmanites* (*Odontocephalus*) *selenurus*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 49, pl. 11B, figs. 15–21; pl. 12, figs. 1–13.

This species appears to be much less common than the closely related species *O. ægeria*. It is represented by a pygidium and the anterior or border of a cephalon, both from the same locality. The latter has but eight or nine of the incisor-like processes on its anterior margin instead of the eleven processes which usually characterize *O. ægeria*. The terminal spines of the pygidium are inclined distinctly upward. There are nine annulations on the pleura, with indications of a tenth.

Distribution.—Occurs in black limestone at Falling Spring, on Sherman Creek, Perry County, Pa.

ODONTOCEPHALUS ÆGERIA Hall.

Plate X, figure 11; Plate XI, figures 3–5; Plate XII, figures 1–5, 7, 8.

1861. *Dalmania ægeria*. Hall, Desc. New Sp. Foss., 1861, p. 57.
1862. *Dalmania ægeria*. Hall, Fifteenth Rept. New York State Cab. Nat. Hist., 1862, p. 85.
1868. *Dalmanites* (*Odontocephalus*) *ægeria?* Meek and Worthen, Geol. Illinois, vol. 3, 1868, p. 417, pl. 10, figs. 4 a, b, c.

1876. *Dalmanites ægeria.* Hall, Illus. Dev. Foss. Crust., 1876, p. 12, figs. 3, 6, 8 [not figs. 1, 2, 7].

1888. *Dalmanites* (*Odontocephalus*) *ægeria.* Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 53, pl. 11B, figs. 1–11.

The collection includes, besides numerous pygidia and fragments of the cephalon, four nearly complete individuals of this species. The largest of these has a length of 86 millimeters. Comparison of these with the published description of the species and the types,[1] though clearly indicating identity with *O. ægeria,* shows some previously undescribed features of the thoracic segments which could not be observed in the types. Hence the thorax and pygidium are here briefly described without specific reference to the anterior portion of the trilobite.

The thorax comprises 10 segments. The pleura are broad and conspicuously sulcate. They are flattened along their inner or proximal half and are abruptly deflected downward at the fulcrum. At the distal extremity they terminate in trowel-like or lanceolate processes, which are deflected backward, forming a fimbriate border, and which have a length of 2 to 5 millimeters in the specimens observed. These fimbriæ are concealed anteriorly, if present, by the genal spines, which extend to or beyond the middle of the thorax. The terminal process on the last pleuron of the thorax extends backward to the third segment of the pygidium on one specimen.

Through the courtesy of Dr. J. M. Clarke and the curator of the American Museum of Natural History, Dr. E. O. Hovey, I have been able to compare my specimens with the types. The only one of the type specimens exhibiting the thoracic portion of the species evidently represents an immature individual and is about one-third the size of some of my specimens of this species. The thoracic fimbria would therefore scarcely be likely to be so prominently developed as on the fossils here figured. Examination of the type specimen, however, showed distinctly the presence of these posteriorly directed tips, which have been partly broken away, with the limestone matrix on four of the pleura adjacent to the pygidium on one side of the trilobite.

The annulations on the pleura of the pygidium, as shown both by the types and the Pennsylvania specimens, are entirely without these terminal processes. The ten or eleven annulations on the pygidium terminate on a smooth, gently rounded border. The axis has ten distinct and two or more indistinct annulations. Examination of the pygidia of the types, two of which are well preserved, fails to disclose any indication of the double axial row of tubercles on the axis, which is said to be one of the distinguishing features of this species.[1] It may be, therefore, that they characterize a species distinct from *O. ægeria*. In the number of pleura on the pygidium the types show some differences. The original of Hall and Clark's figure 3, plate 11B,[1] has but nine pleura and eight annulations on the axis, whereas the other two of the types examined have each eleven pleura and nine annulations. The smaller number belongs to a much smaller individual and hence may be attributable to immaturity. In my collection the usual number of annulations on the pygidium is ten or eleven. One specimen, however, shows eleven, with traces of two others.

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[1] Specimens 4258–4260, catalogue type specimens of Paleozoic fossils in Bull. New York State Mus. No. 65, 1903, p. 679. Specimen 4067, catalogue of types, Bull. Am. Mus. Nat. Hist., vol. 11, pt. 3, 1900, p. 342.

Distribution.—Alinda, New Bloomfield, and Blair County, Pa., and Clifton Forge, Va.

Genus **PHÆTHONIDES** Angelin.

PHÆTHONIDES GEMMÆUS Hall and Clarke.

Plate XIII, figures 11,12.

1888. *Phæthonides gemmæus*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 136, pl. 24, figs. 32–36.

This species is represented by a portion of a pygidium having a length of about 3 millimeters. The comparatively small posterior limb of each annulation terminates at the inner margin of the broad, somewhat flattened border, whereas the anterior limb extends beyond the border and terminates in a spine. From four to six blunt spines or tubercles mark the surface of each anterior limb of the annulations.

Distribution.—Mendota, Va.

Genus **CONOLICHAS** Damer.

CONOLICHAS cf. HISPIDUS Hall and Clarke.

1876. Cf. *Acidaspis* (*Teratapsis*) *Eriopsis*. Hall, Illus. Dev. Foss., 1876, pl. 19, figs. 8, 9.

1888. Cf. *Lichas* (*Conolichas*) *hispidus*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 77, pl. 19A, figs. 14, 17, 18.

The collection contains one imperfect pygidium which probably belongs to this species.

Distribution.—Ridgeville, W. Va.

Genus **CYPHASPIS** Burmeister.

CYPHASPIS cf. STEPHANOPHORA Hall and Clarke.

Plate XIII, figure 2.

1888. Cf. *Cyphaspis stephanophora*. Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 142, pl. 24, figs. 2–6.

The specimens which are closely related to if not identical with this species include a glabella and one of the free cheeks. They occur in a soft, blocky black shale. Their appearance is sufficiently indicated by the figures.

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[1] Natural history of New York, Paleontology, vol. 7, 1888, p. 54.

Distribution.—Berkeley Springs, W. Va.

Genus LICHAS Dalman.

LICHAS (ARGES) CONTUSUS Hall and Clarke var.

Plate XIII, figure 1.

1888. Cf. *Lichas (Arges) contusus.* Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 83, pl. 19B, figs. 3-6.

This species is represented by a single glabella. It does not differ very materially from the specimens figured by Hall and Clarke except in its much smaller size. The length of the specimen figured is only 2 millimeters.

Distribution.—Mendota, Va.

Genus ACIDASPIS Murchison.

ACIDASPIS CALLICERA Hall and Clarke.

Plate XIII, figures 3-10.

1888. *Acidaspis callicera.* Hall and Clarke, Nat. Hist. New York, Paleontology, vol. 7, 1888, p. 69, pl. 16B, figs. 1-13.

This small but characteristic Onondaga trilobite is represented in the collection by free cheeks, with short marginal and long genal spines, from a number of localities ranging from central Pennsylvania to southwestern Virginia. These generally show about 12 marginal spines and a strong lateral spine branching from near the base of the genal spine. Spinelike tubercles mark the upper surface. Representatives of the glabella and pygidium of this species are comparatively rare. The best specimens are shown by the figures.

Distribution.—Alinda and New Bloomfield, Pa.; Fort Seybert, W. Va.; and Mendota, Va.

Genus DALMANITES Barrande.

DALMANITES sp. undet.

Plate XI, figure 2.

The collection includes a single cephalon (here figured) of uncertain specific affinities but somewhat resembling *Dalmanites anchiops*. The cephalon shows the crenulated border at the anterior margin of the glabella, the right free cheek, and the facial suture. Most of the remainder of the cephalon is wanting.

Distribution.—Rees Tannery, south of Keyser, W. Va.

OSTRACODA.[1]

Genus BOLLIA Jones and Holl.

BOLLIA UNGULA Jones.

Plate IX, figures 9, 10.

1889. *Bollia ungula.* Jones, Am. Geologist, vol. 4, 1889, pp. 338–339, pl. opp. p. 242, figs. 10–13, 1889.

Jones's original description follows:

> Prof. Claypole's specimens are well-preserved casts in buff-colored, noncalcareous shales from the Marcellus limestone of Perry County, Pa. (near New Bloomfield). There are several, and they vary from 1 to 2½ millimeters in length. The proportions of some of the best are given in the figures 10 to 13, magnified 15 diameters. In some respects they resemble *Bollia lata* Hall;[2] but they are larger, and the central curved ridge is much thinner at its curve, whereas in the specimens from New York State the curve is thicker just there, and is not so symmetrical throughout as in the Pennsylvania specimens. Hence I prefer to regard the latter as specifically distinct, and to adopt Prof. Claypole's manuscript specific name [3] (having reference to the hoof-like ridge), than to refer them to *Bollia lata.* A hollow cast of the outside and one presumably perfect valve give evidence of a smooth exterior.
>
> The slight variations in the shape and proportions of the curved subcentral ridge and of the marginal ridge are well shown in the figures.

This species is one of the most abundant ostracodes found in the fauna. My collection contains numerous specimens of the species, from the type locality at New Bloomfield, which are identical in every respect with the specimens found in Maryland, Virginia, and West Virginia. The reference of the species to the Marcellus limestone by Jones is, of course, based on Claypole's opinion as to the horizon of the beds which furnished this and other ostracodes described by Jones from New Bloomfield. It is significant that all stratigraphic records of the New Bloomfield specimens made since their description places the species lower than the Marcellus shale. Ulrich [4] has figured it from the horizon of the Onondaga limestone at the Falls of the Ohio, and in an unpublished paper Ulrich and Bassler have recorded it from the lower Oriskany in Maryland.

Distribution.—Hollidaysburg, New Bloomfield, McVeytown, Pa.; Cumberland and Tonoloway, Md.; Rees Tannery, south of Keyser, W. Va.; Bells Valley and Clifton Forge, Va.

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[1] In connection with questions of correlation, with which this paper is primarily concerned, the old and better-known species are of more interest than the new ones. The former alone will be considered. The collection contains some new species and several specimens of doubtful specific or generic identity. These new and doubtful forms will be referred to special students of this group and will not be taken up in this paper. Since the original descriptions of the figured species are widely scattered in publications not easily accessible to most students, it has seemed desirable to quote them in full.

[2] Natural history of New York, Paleontology, vol. 2, 1852, p. 301, pl. A 66, figs 10a, b, d (not figs. c and e), also some in British Museum. Jones says: "I may here mention that I have to refer *lata* and *symmetrica* to *Bollia,* and *spinosa* to *Æchmina.*"

[3] This name was never published by Claypole.

[4] Jour. Cincinnati Soc. Nat. Hist., vol. 13, 1891, p. 188, pl. 14, figs. 6a, b.

BOLLIA OBESA Ulrich.

Plate IX, figure 8.

1891. *Bollia obesa.* Ulrich, Jour. Cincinnati Soc. Nat. Hist., vol. 13, 1891, p. 189, pl. 14, figs. 5a, b, c.

Ulrich's original description follows:

> Size of valve: Length, 1.52 millimeters; height, 0.98 millimeter; thickness, 0.5 millimeter. Carapace subpentagonal, ends nearly equal, strongly curved, back straight, short, dorsal angles obtuse, ventral edge produced in the middle. Marginal portion of valves thick, causing them to appear unusually ventricose. Horseshoe ridge unsymmetrical, with bulbous extremities, the anterior knob oval and reaching the dorsal edge, the posterior one larger, more nearly round, and terminating a short distance within the dorsal margin. This species is not likely to be mistaken for any other known to me. Though clearly a true *Bollia*, it is very different in its general appearance from the associated *B. ungula* Jones. Position and locality: Devonian Bryozoa bed, Falls of the Ohio.

This species is associated with *B. ungula* but is less abundant.

Distribution.—Blair County, Pa.; Cumberland and Tonoloway, Md.; Ridgeville, W. Va.; Bells Valley and Little Moccasin Gap, Va.

Genus BYTHOCYPRIS Brady.

BYTHOCYPRIS FAVULOSA Jones.

Plate IX, figures 13–15.

1889. *Bythocypris favulosa.* Jones, Am. Geologist, vol. 4, 1889, p. 338, pl. opp. p. 342, figs. 1 and 2a, b, c.

Jones's original description follows:

> These small specimens are only casts, and are doubtfully referred to *Bythocypris*, as the genus most convenient to receive them according to their subovate-oblong shape.[1] The hollow cast and another similar but imperfect cast show a coarsely reticulate or honeycomb-like structure, which holds the place of the external surface of the valve. This is not an unusual ornament of some ostracodous valves; but it is here very coarse in proportion to the area of the valve, and it is unusual in such simple cypridiform species as the *Bythocypris*, etc. One specimen is about 1 millimeter, and the other a little more in length. From buff-colored noncalcareous shale of the Marcellus limestone,[2] Perry County, Pa., near New Bloomfield.

The figures represent specimens from the same locality which supplied the types of the species. The peculiar honeycomb-like surface markings of this species serve to distinguish it from any other ostracode in the fauna.

Distribution.—This is a common and widely distributed form. It is represented in the collections from the following localities: New Bloomfield and Blair County, Pa.; Bells Valley, Clifton Forge, Little Moccasin Gap, and Mendota, Va.

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[1] For some other Paleozoic ostracodes referable to this genus, see Annals and Mag. Nat. Hist., 5th ser., vol. 18, 1886, p. 250, etc.; vol. 19, 1887, p. 184, etc.

[2] In the Hamilton group of the Upper Helderberg (Middle Devonian of the United States).

Genus ULRICHIA Jones.

ULRICHIA CONRADI Jones.

Plate IX, figure 12.

1890. *Ulrichia conradi.* Jones, Quart. Jour. Geol. Soc. London, vol. 46, 1890, p. 544, fig. 2.

Jones's original description follows:

Length, 0.8 millimeter; height, 0.46 millimeter. A small left valve, suboblong, straight on the back, obliquely curved below, rounded at the ends, the posterior higher and fuller than the anterior. Two largish prominent knobs, oval in section and obliquely peaked (much too neatly oval in the figure), divide the dorsal region in three nearly equal portions; the front tubercle is smaller than the other. The surface of the valve is faintly reticulated, and has along the free borders a neat marginal ridge.

This species is represented in the collections by a mold of a single individual, which shows the two dorsolateral knobs of unequal size and the reticulated surface characterizing the species.

Distribution.—McVeytown, Pa.

Genus OCTONARIA Jones.

OCTONARIA STIGMATA Ulrich.

Plate IX, figure 11.

1891. *Octonaria stigmata.* Ulrich, Jour. Cincinnati Soc. Nat. Hist., vol. 13, 1891, p. 193, pl. 16, figs. 8 a, b.

Ulrich's original description follows:

It is very difficult to distinguish the back from the ventral edge, and the anterior from the posterior end in species of this peculiar genus. Species variable, valves with a raised and longitudinally ridged area occupying most of the surface. Ridges more or less irregularly thickened at intervals, or united by a greater or less number of crossbars, producing a coarse network. The typical form is ovoid or subrhomboidal in shape, with the anterior extremity the narrowest; posterior end strongly curved in the lower half, sloping forward in the upper half; ventral edge gently convex, curving neatly up into the anterior curve which is the most prominent above the middle; back straight, without cardinal angles. Counting the marginal ridge of the elevated area, there are five longitudinal ridges in the anterior half. In the posterior half they become irregular. Size: Length, 0.88 millimeter; height, 0.53 millimeter.

Distribution.—Comparatively rare, having been found in only one locality 2 miles west of Canoe Creek, Blair County, Pa.

Genus LEPERDITIA Rouault.

LEPERDITIA? cf. SUBROTUNDA Ulrich.

Plate IX, figure 7.

1891. *Leperditia ? subrotunda.* Ulrich, Jour. Cincinnati. Soc. Nat. Hist., vol. 13, 1891, p. 181, pl. 16, figs. 1 a, b, c.

Ulrich's original description follows:

Size of left valve: Length, 0.68 millimeter; thickness, 0.21 millimeter. Carapace small, short, rounded, uniformly convex, encircled, except at the strongly convex ventral edge, by a flattened border, widest in the posterodorsal region. Dorsal edge scarcely straight, gently curving into the ends. Ventral overlap distinct. Surface smooth and even, without eye tubercle or muscle spot. The development of a flange at the dorsal border is a very unusual feature in this genus. *L. sinuata* Hall has nearly the same shape, but is without a flange, and so far as known its valves do not overlap at the ventral margin. I am inclined to believe that species of this character ought to be arranged with *Aparchites* rather than *Leperditia*. Position and locality: Devonian Bryozoa bed, Falls of the Ohio. Rare.

A circular or subcircular ostracode occurs sparingly as casts of the shell at three or four localities represented by the collections. These agree with Ulrich's figures of *L. subrotunda*, except that the projecting flattened border feature appears to be developed but slightly or not at all; the form here compared with *L. subrotunda* may represent a closely related species.

Distribution.—Hollidaysburg and Upper Reese, Blair County, Pa.; Berkeley Springs, W. Va.; and Little Moccasin Gap, Va.

PLATE II.

PLATE II.

ZAPHRENTIS cf. SIMPLEX (p. 66).

FIGURE 1. Lateral view. New Bloomfield, Pa.

CYSTIPHYLLUM AMERICANUM (p. 67).

FIGURE 2. Lateral view of specimen with exfoliated epitheca. Big Stone Gap, Va.

PLEURODICTYUM sp. undet. (p. 66).

FIGURE 3. Natural cast, showing filling of intramural pores between the cells. Clifton Forge, Va.

BLOTHEROPHYLLUM DECORTICATUM (p. 67).

FIGURE 4. Lateral view of specimen with eroded epitheca. Big Stone Gap, Va.

POLYGNATHUS sp. undet. (p. 67).

FIGURE 5. Incomplete jaw. The tips of four or five teeth which were discernible on the specimen are not brought out in the illustration. Tonoloway, Md.

LINGULA cf. LIGEA (p. 69).

FIGURE 6. Pedicle (?) valve. Blair County, Pa.

PHOLIDOPS cf. AREOLATA (p. 70).

FIGURE 7. Natural mold of the exterior of the pedicle valve.

8. Natural cast of the interior of the pedicle valve. The slender impressed median line of the figure has about twice the proper length. It is conspicuous only near the apex of the crescent-shaped depression, × 5. Bells Valley, Va.

ORBICULOIDEA LODIENSIS var. MEDIA (p. 69).

FIGURE 9. Exterior of a partly exfoliated brachial valve. Bells Gap, Va.

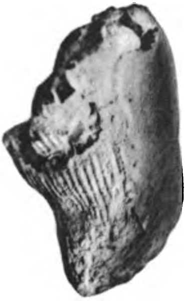
10. Interior of a partly exfoliated pedicle valve. The more exfoliated portions are smooth, not striated, as indicated by figure. Bells Gap, Va.

11. Natural cast of the exterior of pedicle valve, showing concentric striæ. East of Cumberland, Md.

LEPTOSTROPHIA PERPLANA (p. 75).

FIGURE 12. Natural cast of interior of pedicle valve. New Bloomfield, Pa.

13. Exterior of pedicle valve of a small specimen. Schuylkill Haven, Pa.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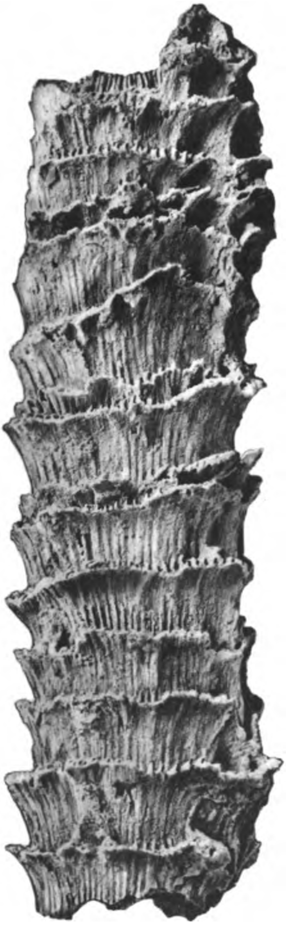
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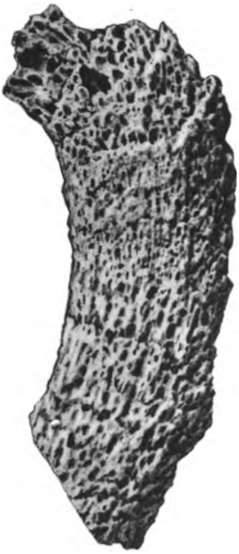
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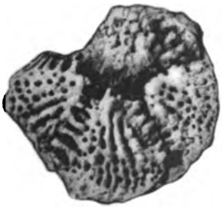
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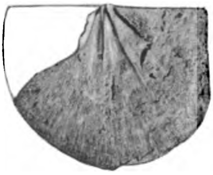
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ONONDAGA FAUNA

PLATE III.

PLATE III.

LEPTOSTROPHIA PERPLANA (p. 75).

FIGURE 1. Enlargement of part of the surface of a brachial valve, showing fine concentric striæ, × 4. Schuylkill Haven, Pa.

STROPHEODONTA INEQUISTRIATA (p. 76).

FIGURE 2. Natural cast of interior of a fragmentary pedicle valve, which has been slightly compressed laterally, × 3.
3. Partly exfoliated pedicle valve. Blair County, Pa.
4. Gutta-percha cast of the exterior, × 3.
Figures 2 and 4 illustrate the interior and exterior of the same individual. New Bloomfield, Pa.

STROPHEODONTA PATERSONI (p. 75).

FIGURE 5. Fragment of a pedicle valve, × 2. Mendota, Va.
6. Fragmentary brachial valve, × 3. Little Moccasin Gap, Va.

SCHUCHERTELLA PANDORA (p. 76).

FIGURE 7. Pedicle valve of a small shell. Little Moccasin Gap, Va.
8. Brachial valve. Mendota, Va.

CHONETES ARCUATUS (p. 73).

FIGURE 9. Exterior of a partly exfoliated pedicle valve.
FIGURES 10, 11. Natural cast of the interior of a pedicle valve, showing hinge teeth, area, etc. Little Moccasin Gap, Va.
FIGURE 12. Natural mold of the exterior of part of a brachial valve.

CHONETES MUCRONATUS (p. 71).

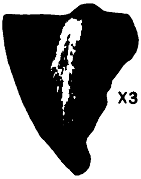
FIGURE 13. Small pedicle valve, × 3. Cumberland, Md.
14. A pedicle valve of average size and appearance, showing the long spines, × 2. Cumberland, Md.

CHONETES HEMISPHERICUS (p. 70).

FIGURE 15. Pedicle valve, × 2.
16. Lateral profile of same specimen, × 2. Schuylkill Haven, Pa.

CHONETES cf. SETIGERUS (p. 71).

FIGURE 17. Pedicle valve, × 2. Selinsgrove Junction, Pa.



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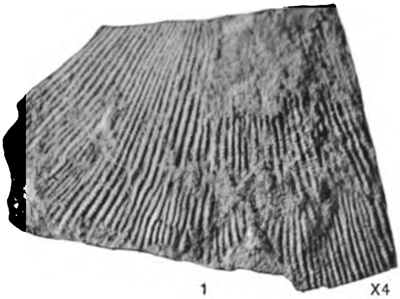

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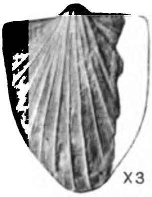

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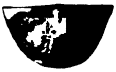

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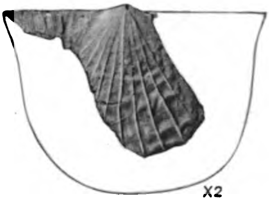

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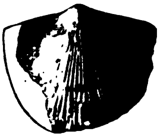

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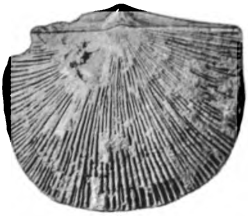

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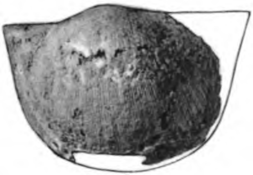

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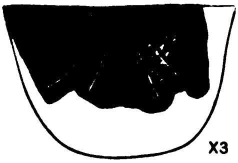

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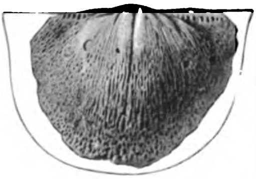

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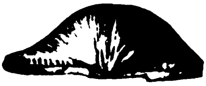

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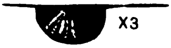

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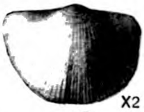

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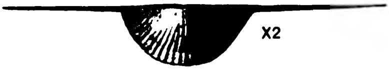

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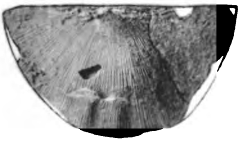

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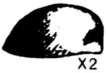

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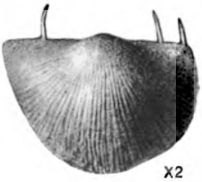

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ONONDAGA FAUNA

PLATE V.

PLATE V.

PHOLIDOSTROPHIA PENNSYLVANICA n. sp. (p. 74).

FIGURE 1. Type specimen; pedicle valve, × 3. East of Cumberland, Md.
2. Natural cast of the interior of a pedicle valve, showing short and very slender median septum. Berkeley Springs, W. Va.

PRODUCTELLA NAVICELLA (p. 78).

FIGURE 3. Anterior of a pedicle valve. Schuylkill Haven, Pa.

CYRTINA HAMILTONENSIS (p. 81).

FIGURE 4. Brachial view of a natural cast. New Bloomfield, Pa.

STROPHALOSIA TRUNCATA (p. 77).

FIGURE 5. Natural cast of the interior of a brachial valve, showing crenulated hinge line and very slender septum, × 2. Ridgeville, W. Va.
6. Pedicle valve, showing truncated umbone, × 2.
7. Exterior of brachial valve, showing crenulated margin at hinge line, × 2. Ridgeville, W. Va.

ANOPLIA NUCLEATA (p. 73).

FIGURES 8, 11. Views of natural molds of two pedicle valves, showing two types of median septum, one terminating anteriorly in an indistinct Y-shaped process, × 3. Mendota, Va.
FIGURE 9. Cardinal view of natural cast of pedicle valve, showing filling of oblique cardinal tubes, × 5. Mendota, Va.
10. Pedicle view. Mendota, Va.

DALMANELLA LENTICULARIS (p. 79).

FIGURE 12. Brachial view, × 2.
13, 16. Natural molds of the interior of two brachial valves.
14, 15. Two fragmentary natural molds of pedicle valves.
All the specimens are from Berkeley Springs, W. Va.

RHIPIDOMELLA VANUXEMI (p. 79).

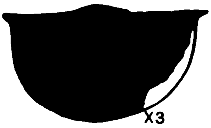
FIGURES 17, 18. Two natural casts of brachial valves. New Bloomfield, Pa.
19. Exfoliated pedicle valve. Mendota, Va.

AMBOCŒLIA cf. NANA (p. 83).

FIGURE 20. Pedicle valve, × 2. McVeytown, Pa.
21–23. Pedicle, brachial, and lateral views of another specimen, × 2. McVeytown, Pa.

ATRYPA RETICULARIS (p. 80).

FIGURES 24, 25. Brachial and anterior profiles of exfoliated shell. New Bloomfield, Pa.



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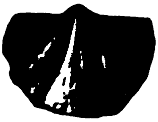

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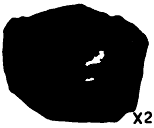

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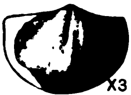

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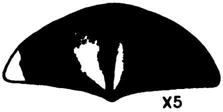

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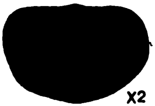

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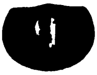

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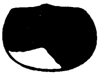

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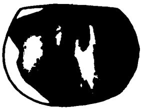

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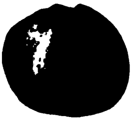

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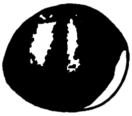

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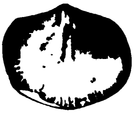

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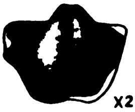

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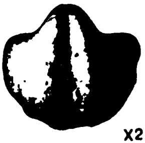

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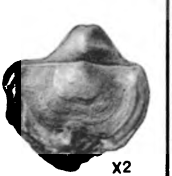

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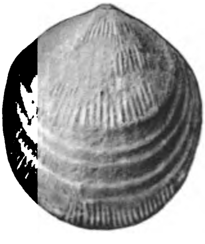

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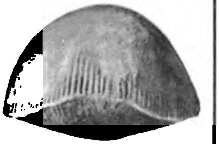

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ONONDAGA FAUNA

PLATE VI.

PLATE VI.

ANOPLOTHECA ACUTIPLICATA (p. 84).

FIGURES 1–3. Brachial, anterior, and pedicle views of one of the types. Photographic reproductions of the specimen illustrated by Hall, Nat. Hist. Paleontology, vol. 4, pl. 57, figs. 34–37.

4–6. Brachial, anterior, and pedicle views of an exfoliated shell. Blair County, Pa.

7–9. Three specimens showing variation in anterior profile. These are exfoliated specimens, hence do not show the characteristic rugose concentric striæ. Blair County, Pa.

10, 11. Brachial and pedicle views of a slightly distorted and partly exfoliated shell having concentric striæ. New Bloomfield, Pa.

12. Brachial view of another individual. Clifton Forge, Va.

13. Interior of brachial valve from an artificial cast. Ridgeville, W. Va.

14. Natural cast of the interior of a brachial valve. Three miles east of Cumberland, Md.

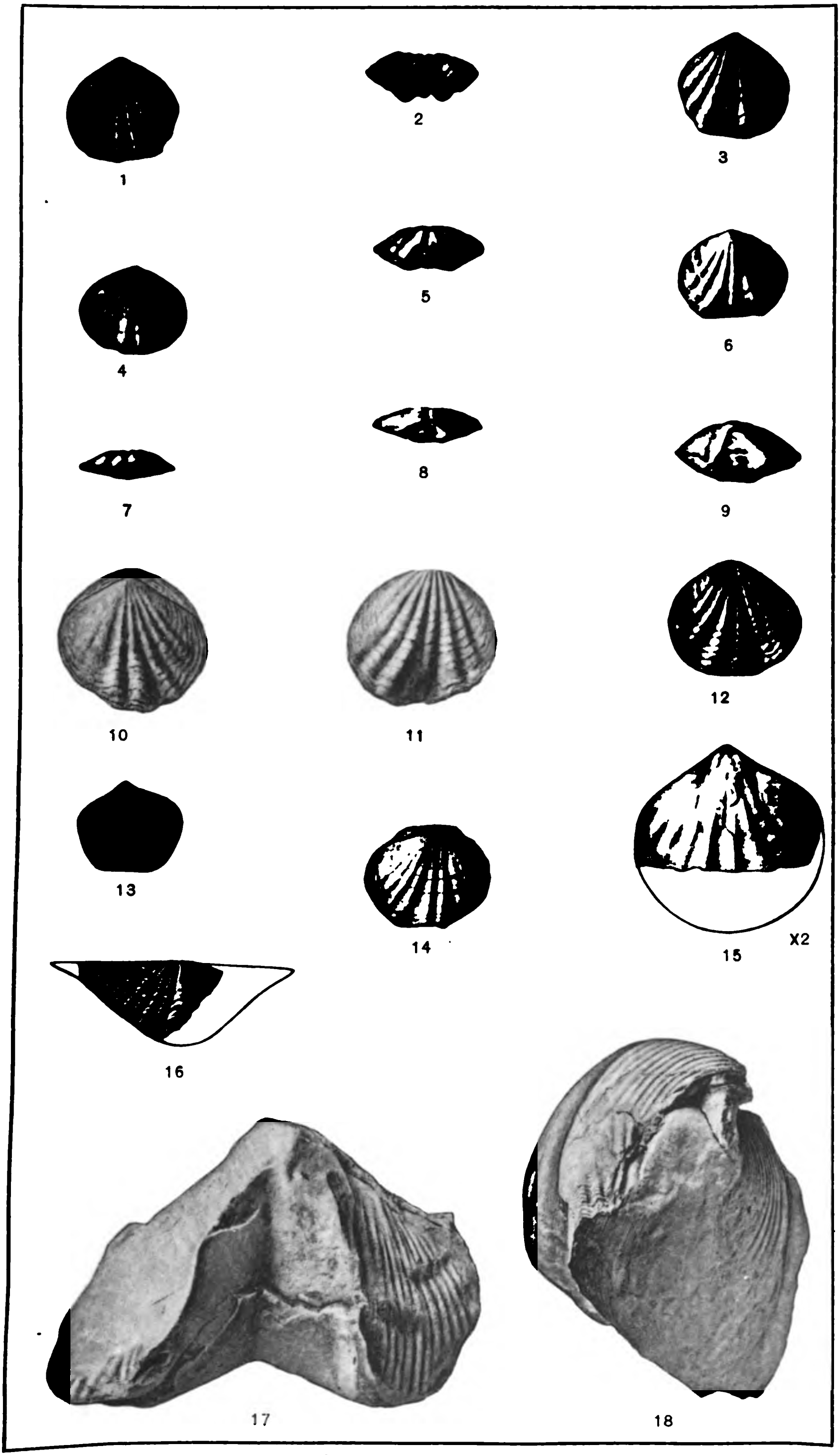
15. Natural mold of the interior of a brachial valve, × 2. East of Cumberland, Md.

SPIRIFER VARICOSUS (p. 82).

FIGURE 16. Fragmentary brachial valve. Mendota, Va.

SPIRIFER ACUMINATUS (p. 81).

FIGURES 17, 18. Anterior and lateral profiles of a partly exfoliated shell. The figures fail to show the fine transverse striæ in the sinus and the bifurcating plications exhibited by the specimen. Schuylkill Haven, Pa.



ONONDAGA FAUNA

PLATE VII.

PLATE VII.

CRANÆNA cf. ROMINGERI (p. 86).

FIGURES 1, 2. Two individuals showing interior aspect of brachial and pedicle valves, × 2. Ridgeville, W. Va.

NUCLEOSPIRA CONCINNA (p. 86).

FIGURE 3. Pedicle view, × 3. Mendota, Va.
4, 5. Natural casts of the interior of pedicle valves. Mendota, Va.

RETICULARIA cf. MODESTA (p. 82).

FIGURE 6. Brachial valve, × 2. Mendota, Va.

MERISTELLA NASUTA (p. 85).

FIGURE 7. Exfoliated pedicle valve showing muscular impression. Mendota, Va.

PTEROCHÆNIA FRAGILIS (p. 90).

FIGURE 8. Fragmentary right valve, × 2. Poplar Hill, Va.
9. Left valve, × 2. Poplar Hill, Va.

PALÆONEILO cf. CONSTRICTA (p. 87).

FIGURE 10. Left valve. New Bloomfield, Pa.

CYPRICARDINIA INDENTA (p. 94).

FIGURE 11. Fragmentary right valve, × 3. Little Moccasin Gap, Va.
12. Fragment of natural mold of a valve, showing surface marking, × 5. Mendota, Va.

NUCULITES MODULATUS n. sp. (p. 89).

FIGURE 13. Type specimen. Ridgeville, W. Va.
14. Another individual. Ridgeville, W. Va.

NUCULA cf. CORBULIFORMIS (p. 88).

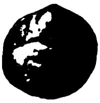
FIGURE 15. Fragmentary right valve, × 2. Berkeley Springs, W. Va.

LUNULICARDIUM CURTUM (p. 89).

FIGURE 16. Right valve. Ridgeville, W. Va.

PANENKA cf. DICHOTOMA (p. 96).

FIGURE 17. Fragmentary right valve. Ridgeville, W. Va.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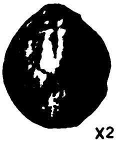
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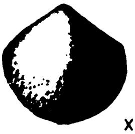
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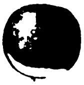
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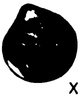
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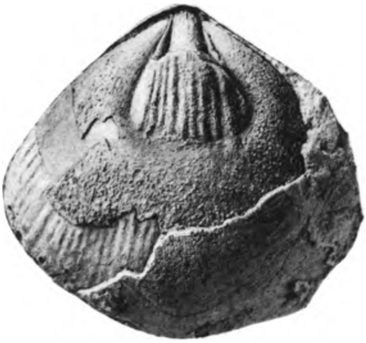
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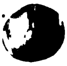
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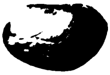
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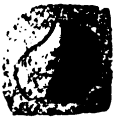
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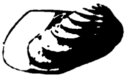
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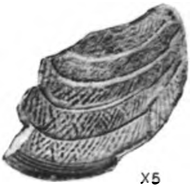
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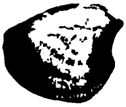
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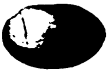
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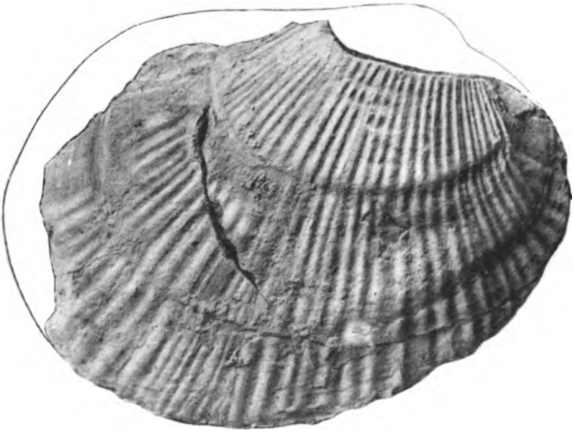
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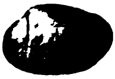
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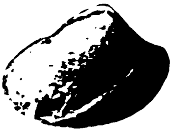
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ONONDAGA FAUNA

PLATE VIII.

PLATE VIII.

MODIOMORPHA SUBALATA (p. 93).

FIGURE 1. An imperfect right valve.

AVICULOPECTEN EQUILATERA (p. 93).

FIGURES 2 to 3. Two left valves showing variation in erectness of the shell, × 2. Blair County, Pa., and Ridgeville, W. Va.

PTERINEA sp. undet. (p. 91).

FIGURE 4. Left valve showing surface ornamentation. Little Moccasin Gap, Va.

LEIOPTERIA LÆVIS (p. 95).

FIGURE 5. Left valve, × 2. 3 miles east of Cumberland, Md.

ACTINOPTERIA MURICATA (p. 92).

FIGURE 6. Left valve showing radiating and concentric striæ.

PLEUROTOMARIA CRASSA n. sp. (p. 102).

FIGURES 7, 8. Type specimen showing ornamentation on opposite sides, × 2. Blair County, Pa.

LOXONEMA HAMILTONIÆ (p. 100).

FIGURE 9. Flattened specimen showing transverse striæ. Ridgeville, W. Va.
10. Small specimen of the same species. New Bloomfield, Pa.

NATICOPSIS sp. undet. (p. 98).

FIGURE 11. Lateral view, × 4. Ridgeville, W. Va.

PLATYOSTOMA TURBINATA (p. 97).

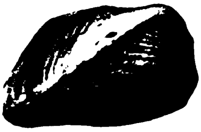
FIGURE 12. Exfoliated shell. The figure fails to show the revolving band and transverse striæ, traces of which are preserved by the specimen. McVeytown, Pa.

PLATYCERAS THETIS (p. 99).

FIGURE 13. Compressed specimen, in which the anterior margin of the shell is broken away.

BELLEROPHON LEDA (p. 101).

FIGURE 14. View showing revolving and fine transverse lines, × 3. Schuylkill Haven, Pa.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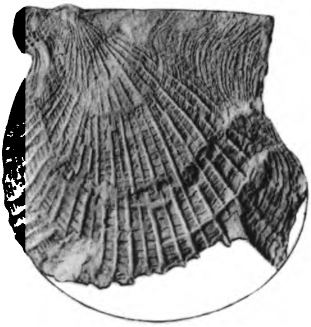
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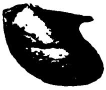
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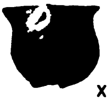
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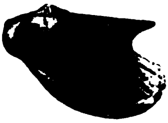
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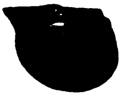
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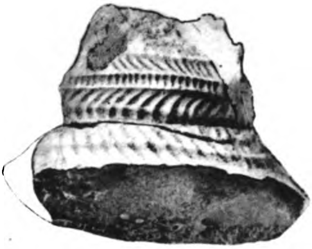
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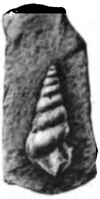
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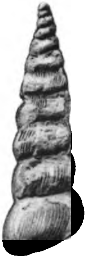
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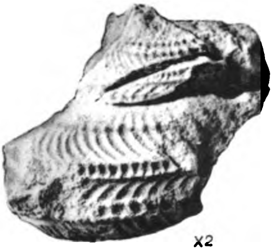
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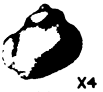
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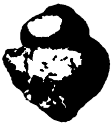
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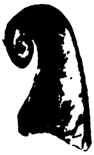
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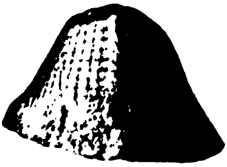
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ONONDAGA FAUNA

PLATE IX.

PLATE IX.

COLEOLUS? CURVATUS n. sp. (p. 105).

FIGURE 1. Type specimen. New Bloomfield, Pa.
2. Another individual, × 2. Blair County, Pa.

BACTRITES ACICULUM (p. 104).

FIGURE 3. Fragmentary tube. Sassin, Va.

TENTACULITES GRACILISTRIATUS (p. 103).

FIGURE 4. External impression of a specimen in shale, × 5. Bells Valley, Va.

TENTACULITES SCALARIFORMIS (p. 103).

FIGURE 5. Fragmentary specimen, × 4. Mendota, Va.

AGONIATITES EXPANSUS (p. 107).

FIGURE 6. Outline figure showing character of surface striæ. Cumberland, Md.

LEPERDITIA? cf. SUBROTUNDA (p. 115).

FIGURE 7. Right (?) valve, × 20. Little Moccasin Gap, Va.

BOLLIA OBESA (p. 114).

FIGURE 8. Natural cast of a left valve, × 20. New Bloomfield, Pa.

BOLLIA UNGULA (p. 113).

FIGURE 9. Natural cast of a left valve, × 20. Rees Tannery, Mineral County, W. Va.
10. Dorsal view of a slightly distorted specimen, × 20. Ridgeville, W. Va.

OCTONARIA STIGMATA (p. 115).

FIGURE 11. Right valve, × 20. New Bloomfield, Pa.

ULRICHIA CONRADI (p. 115).

FIGURE 12. Natural mold of the exterior of a left valve, × 20. McVeytown, Pa.

BYTHOCYPRIS FAVULOSA (p. 114).

FIGURE 13. Natural mold of the exterior of one of the valves, × 20. New Bloomfield, Pa.
14. Natural mold of exterior of another individual. New Bloomfield, Pa.
15. Natural cast of the interior of a left valve, × 20. New Bloomfield, Pa.

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X2

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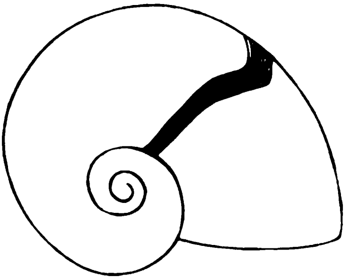
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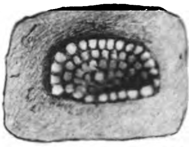
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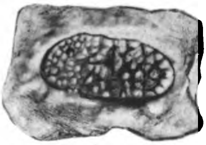
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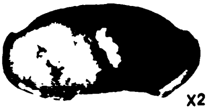
X20

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X20

9

X20

11

10

ONONDAGA FAUNA

PLATE X.

PLATE X.

PHACOPS RANA (p. 107).

FIGURE 1. Internal cast of a cephalon. Bells Valley, Va.
2. Natural cast of a pygidium and a part of a thorax. Bells Valley, Va.
3. View of a small cephalon. Blair County, Pa.
4. View of another specimen. Blair County, Pa.
5. Natural cast of a fragmentary specimen, showing thorax, pygidium, and part of cephalon. New Bloomfield, Pa.

PHACOPS CRISTATA (p. 107).

FIGURE 6. Cephalon and part of the thorax of an enrolled specimen, showing axial and genal spines. Alinda, Pa.
7. Lateral view of an enrolled specimen with a partly crushed glabella, showing genal spine base. Alinda, Pa.
8. Fragmentary thorax and pygidium, showing axial spines. Ridgeville, W. Va.

PHACOPS CRISTATA var. PIPA (p. 108).

FIGURE 9. Fragmentary enrolled thorax referred to this species. Alinda, Pa.
10. Pygidium, showing duplicate character of pleural annulations. New Bloomfield, Pa.

ODONTOCEPHALUS ÆGERIA (p. 109).

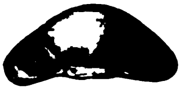
FIGURE 11. Natural cast of a fragmentary specimen. The anterior and right margins of the cephalon have been broken away, and the left cheek has been laterally compressed. Alinda, Pa.

DALMANITES (CORONURA) ASPECTANS (p. 109).

FIGURE 12. Left cheek.
13. Part of a detached eye on same slab and closely adjacent to the preceding specimen, to which it probably belonged. Blair County, Pa.

CRYPHÆUS cf. BOOTHI var. CALLITELES (p. 108).

FIGURE 14. Cast of the interior of a fragmentary cephalon. Ridgeville, W. Va.
15. Another fragmentary cephalon, × 2. Blair County, Pa.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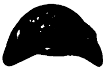
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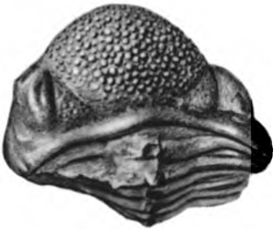
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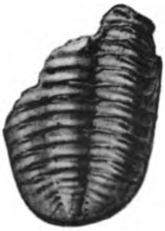
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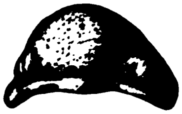
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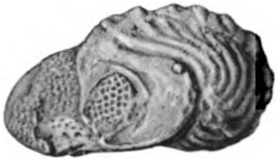
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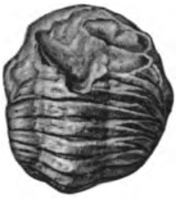
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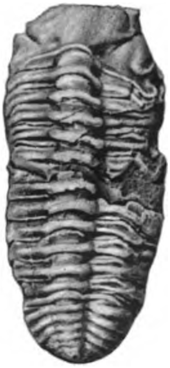
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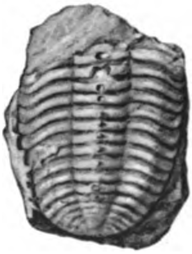
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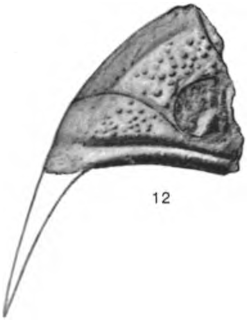
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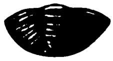
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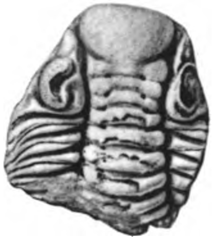
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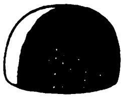
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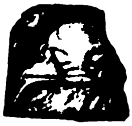
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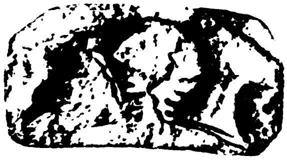
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ONONDAGA FAUNA

PLATE XI.

PLATE XI.

CRYPHÆUS cf. BOOTHI var. CALLITELES (p. 108).

FIGURE 1. Natural cast of a fragmentary cephalon and thorax. The impression of the spine of the left cheek, which is not seen in the figure, extends on the specimen to the third annulation or beyond. The pygidium near the posterior end of thorax probably belongs to another species. New Bloomfield, Pa.

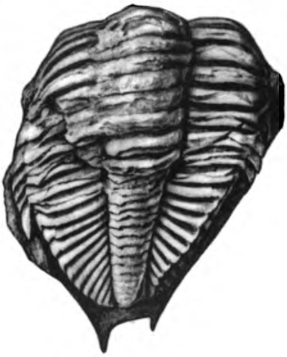
DALMANITES sp. undet. (p. 112).

FIGURE 2. Fragmentary natural mold of a cephalon showing crenulated anterior border in the median portion, × 2. Rees Tannery, Keyser County, W. Va.

ODONTOCEPHALUS ÆGERIA (p. 109).

FIGURE 3. Natural cast of the interior of a fragmentary individual, showing the lanceolate processes at the ends of the pleura below the spine. Alinda, Pa.

4, 5. Posterior portions of two individuals with distorted pygidia, showing the posteriorly directed processes at the outer extremities of the pleuræ. These specimens represent in the main casts of the interior. Alinda, Pa.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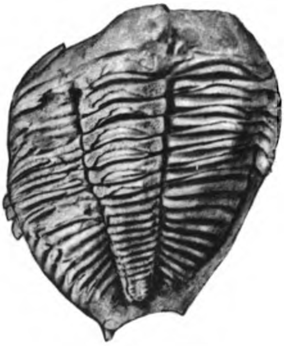
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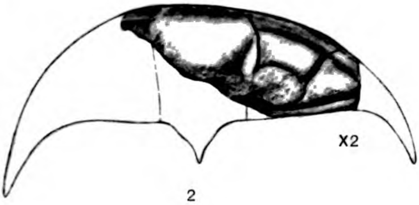

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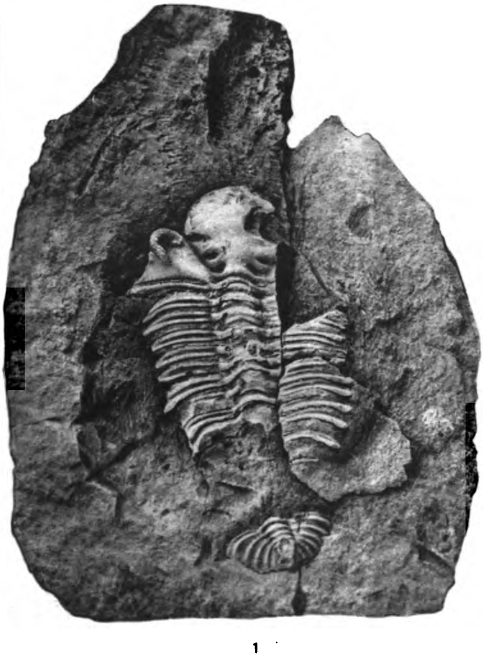
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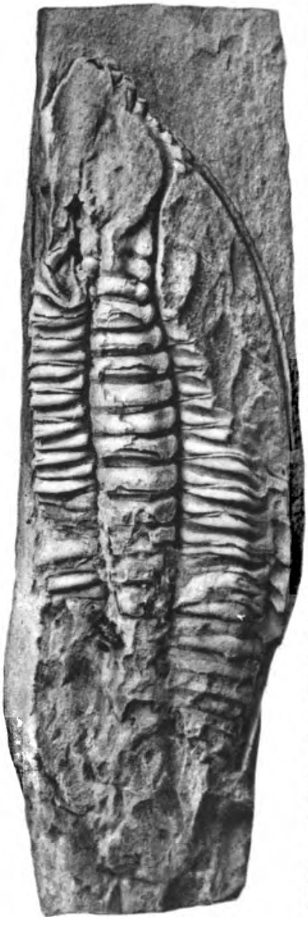
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ONONDAGA FAUNA

PLATE XII.

PLATE XII.

ODONTOCEPHALUS ÆGERIA (p. 109).

FIGURE 1. A partly exfoliated individual, distorted and somewhat shortened by pressure. Alinda, Pa.

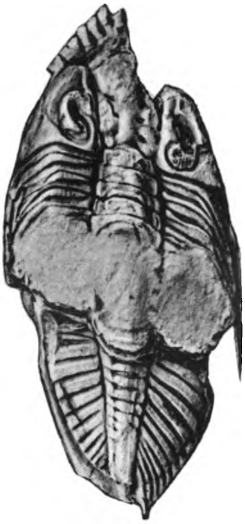
2, 3. Two views of an individual having the tail doubled under the thorax. With the exception of the anterior portion of the pygidium the specimen is mainly a cast of the interior. New Bloomfield, Pa.

4–5. Two specimens of the denticulated frontal doublure, showing some of the variations in its outline. Figure 4 shows the second from the left of the toothlike processes imperfectly developed. The localities represented are: No. 4, McVeytown; No. 5, Blair County.

7, 8. Large individuals in which the test is but slightly exfoliated. Alinda, Pa.

ODONTOCEPHALUS SELENURUS (p. 109).

FIGURE 6. View of portion of denticulated frontal doublure. Falling Spring, Perry County, Pa.



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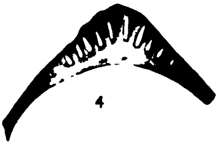

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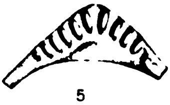

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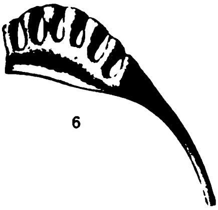

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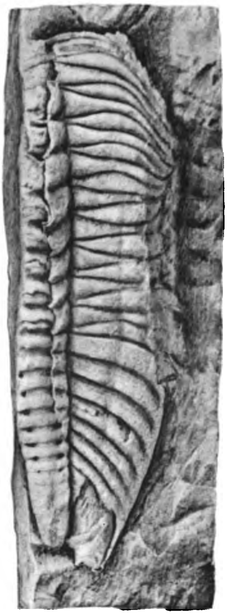

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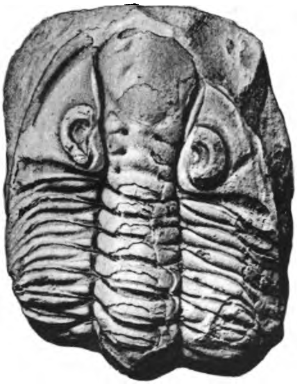

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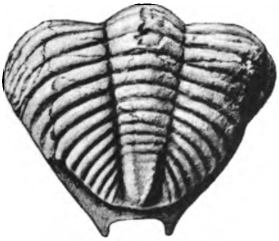

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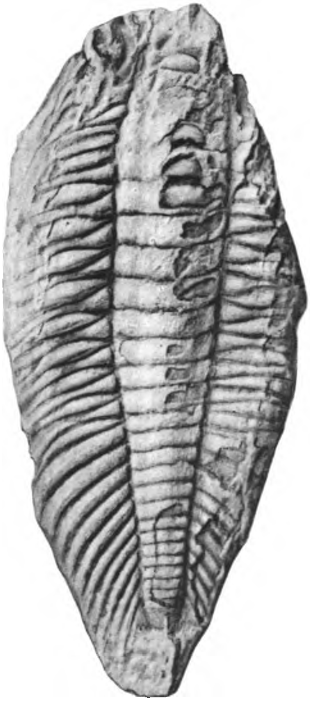

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ONONDAGA FAUNA

PLATE XIII.

PLATE XIII.

LICHAS (ARGES) CONTUSUS var. (p. 112).

FIGURE 1. Fragmentary cephalon, × 5. Mendota, Va.

CYPHASPIS cf. STEPHANOPHORA (p. 111).

FIGURE 2. Fragmentary glabella, × 5. Berkeley Springs, W. Va.

ACIDASPIS CALLICERA (p. 112).

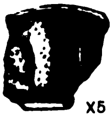
FIGURE 3. Fragmentary glabella, showing imperfectly the notched anterior margin, × 5. Blair County, Pa.

4. Nearly complete glabella, × 3. Blair County, Pa.
5. Natural cast of a portion of the free cheek, showing spinose margin, × 3. Mendota, Va.
6. Natural mold of the interior of a free right cheek, × 3. Berkeley Springs, W. Va.
7. Natural cast of the interior of a right cheek, showing bases of marginal spines and a portion of the long genal spine. New Bloomfield, Pa.
8. Genal spine and a part of the cheek. New Bloomfield, Pa.
9. Wax cast of a pygidium, showing spines but not the tuberculous surface, × 2. New Bloomfield, Pa.
10. Fragmentary pygidium, showing tuberculous surface, × 5. Mendota, Va.

PHÆTHONIDES GEMMÆUS (p. 111).

FIGURE 11. Fragmentary pygidium. The light-colored portion is restored, × 5. Mendota, Va.

12. Natural cast of the interior of a pygidium doubtfully referred to this species, × 2. New Bloomfield, Pa.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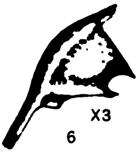
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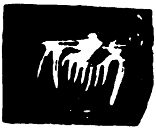
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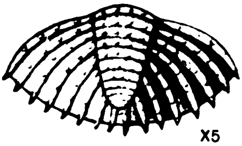
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X3
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SERIES 2

BY

WALDEMAR T. SCHALLER

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MINERALOGICAL NOTES, SERIES 2.

By WALDEMAR T. SCHALLER.

INTRODUCTION.

The several papers here assembled represent in part the results of mineralogical research work carried out by the author in the chemical laboratory of the United States Geological Survey from January 1, 1910, to the end of the fiscal year 1910–11 (June 30, 1911). Earlier reports of a similar nature have been published as "Mineralogical notes" (1903–1904), a part of Bulletin 262, and "Mineralogical notes, series 1" (1905–1909), in Bulletin 490. In addition to these papers a report on the crystallography of ferberite from Colorado was prepared (with Mr. F. L. Hess) for publication in the "Proceedings of the United States National Museum," and a report on the gem-tourmaline field of southern California has been nearly finished.

Several of the papers contained herein were originally written in conjunction with some of the geologists of the Survey. In these papers full credit has been given for their contributions, several of which have been somewhat rearranged.

A STUDY OF THE RUTILE GROUP.

INTRODUCTION.

The rutile group, as discussed in this paper, comprises the minerals rutile, cassiterite, mossite, tapiolite, nigrine, iserite, ainalite, ilmenorutile, and strüverite,[1] all of which occur well crystallized. Recent analyses of ilmenorutile and strüverite in papers by Brögger[2] and by Prior and Zambonini[3] make it possible to study the entire group fairly conclusively.

The separation of titanium, columbium, and tantalum, when they are found together in a mineral, is not alone a most difficult operation, but one in which accurate results are not yet attainable. Interpretation of the analyses of such a group of minerals is therefore difficult because the accuracy of the analytical figures is considerably in doubt. Notwithstanding this primary difficulty, the explanation herein offered of the composition of the rutile group[4] serves to interpret the natural occurrences of these minerals and seems free from serious objection.

CHARACTERISTICS OF THE RUTILE GROUP.

The rutile group is well defined and striking. It comprises a number of minerals generally considered as well-established species, though all but two of them are of rare occurrence. A very striking fact is that these minerals are very similar crystallographically; for not only do they all crystallize in the tetragonal system with nearly the same value for the *c* axis ($c=0.6$), but they possess a further peculiarity that at once shows their close geometrical kinship in that they form twin crystals (twinning plane $\{101\}$), distorted in a direction parallel to the intersection of the two unit pyramids (111) and $(1\bar{1}1)$. This peculiar distortion and twinning gave rise to the supposed species, skogbölite and ixiolite, which are, in fact, only twinned tapoilite crystals. If, now, it can be shown that there is a similar close chemical relationship between these minerals, sufficient evidence and material will be provided for a satisfactory study of this group.

---

[1] Several other minerals doubtless belong to this group. Among these are zircon, thorite, and platnerite, but they are not included in the present discussion because the elements zirconium, thorium, and lead do not enter, so far as known, into the composition of the minerals here discussed.

[2] Brögger, W. C., Die Mineralien der südnorwegischen Granit-Pegmatitgänge.—I, Niobate, Tantalate, Titanate und Titanoniobate: Videnskabs-Selskabets Skrifter, Math.-Naturw. Kl., 1906, no. 6.

[3] Prior, G. T. and Zambonini, F., On strüverite and its relation to ilmenorutile: Mineralog. Mag., vol. 15, 1908, p. 78.

[4] All the analyses quoted in this paper have been taken from the literature. The only experimental work done consists of some qualitative tests.

Isomorphous relationships are strongly indicated by these minerals, and have already been suggested by several authors, notably Brögger and Prior.[1] The paper of Brögger is exceptionally rich in suggestions, and many hypotheses here advanced are proposed by him, though some are merely indicated by him as possibilities, their correctness not being demonstrable. The relations of rutile to tapiolite, mossite, and the compound $FeTiO_3$ are frequently brought out in his work. Particularly to the point is his suggestion at the end of the discussion of the relations of ilmenorutile that the occurrence of the compound $FeTiO_3$ in ilmenorutile makes it probable that the pure compound $FeTiO_3$ is possible in the tetragonal modification. Brögger's paper should be carefully read for a full discussion of the relations of these similar compounds.

In short, I would explain this entire group as consisting either of members of an isomorphous family or of mixtures of two or more of such members in varying proportions. The existence of several distinct primary compounds is recognized and three of them occur in nature in a pure state. All the other members of the rutile group can be satisfactorily explained as isomorphous mixtures of two or more of these primary compounds.

PRIMARY COMPOUNDS.

CHIEF PRIMARY COMPOUNDS.

The six most important primary compounds may best be treated by themselves as a group, reserving the minor compounds for subsequent discussion. These chief primary compounds are the following:

Occurrence of chief primary compounds.

Composition.	Formula.	Maximum percentage of occurrence in natural minerals.	Mineral.
Ferrous columbate	$Fe\ (CbO_3)_2$	39.2	
Ferrous tantalate	$Fe\ (TaO_3)_2$	Nearly 100	Tapiolite.
Ferrous titanate	$Fe\ (TiO_3)$	64.0	
Titanyl titanate	$(TiO)\ (TiO_3)$	Nearly 100	Rutile.[a]
Stannyl stannate	$(SnO)\ (SnO_3)$	Nearly 100	Cassiterite.[a]
Ferrous stannate	$Fe\ (SnO_3)$	36.1	

[a] The formulas of rutile and cassiterite are given in the form used by Brögger.

In the following description of the chief primary minerals or compounds just named, only such data as have a bearing on the possible isomorphous relations of the compounds are included. Unless otherwise stated the data are taken from Dana.[1]

---

[1] Op. cit. Rammelsberg (Handb. Mineralchemie, 2e Auflage, II, Specieller Theil, 1875, p. 357) states that the tin oxide present in the analyses of tantalite (probably tapiolite), is to be considered as $FeSnO_3$ in isomorphous admixture. A similar suggestion is offered for the titanium present, which is to be regarded as $FeTiO_3$.

Ferrous columbate.—The mineral known as mossite was described by Brögger,[2] who, on the basis of an analysis which showed columbium and tantalum to be present in molecularly equal quantities, felt justified in putting forth a new name. Pure or even approximately pure (tetragonal) iron columbate had not been found in nature, but Brögger referred the name "mossite" to such tetragonal compounds where the columbate is present in the ratio of 1:1 or 1+:1 of the tantalate. The value of the *c* axis for the isomorphous tapiolite is given by Brögger as 0.65215. Brögger's "mossite," a mixture of columbate and tantalate, has $c = 0.64379$. The value of the *c* axis for the pure ferrous columbate should therefore be about 0.6354. Similarly, the density of the purest tapiolite analyzed, the "skogbölite,"[3] is 7.85. The density of Brögger's "mossite" is given as 6.45. From these data the density of the pure ferrous columbate, $Fe(CbO_3)_2$, is found to be about 5.05, a figure lower than the lowest authentic density (5.26) I could find recorded for columbite, which is for the dimorphous orthorhombic form of iron columbate. Similarly, the density (7.85) for tapolite, $Fe(TaO_3)_2$, is lower than the highest recorded value for tantalite. However, these figures are of uncertain value. "Mossite" often forms the peculiar distorted twinned crystals, elongated parallel to the intersection edge of $(111):(1\bar{1}1)$.

Ferrous tantalate or tapiolite.—The name tapiolite is here used to refer to the pure iron tantalate, $Fe(TaO_3)_2$. Like "mossite," this mineral often forms distorted twin crystals. The values of the *c* axis and the density, which have been given in the preceding paragraph, are 0.65215 and 7.85, respectively.

Ferrous titanate.—The tetragonal ferrous titanate $Fe(TiO_3)$[4] is present in large amount in iserite.[5] It is the admixed component of ferriferous rutile, or nigrine, and occurs in ilmenorutile and strüverite. Its physical properties are not known, but the *c* axis of iserite is close to 0.64 and the density of ferrous titanate has been calculated to be about $5. \pm .25$. (See p. 12.) Janovsky[6] describes iserite as occurring in tetragonal crystals, similar to rutile, twinned on $\{101\}$.

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[1] Dana, E. S., System of mineralogy, 6 ed., 1892.

[2] Brögger, W. C., Über den Mossit und über das Krystallsystem des Tantalit (Skogbölit) aus Finnland: Videnskabsselskabets Skrifter.—I, Math. naturw. Kl., 1897, No. 7, p. 19.

[3] Dana, E. S., System of mineralogy, p. 734, analysis No. 7.

[4] This is the same compound which, in its trigonal or rhombohedral polymorphous form, exists as the mineral ilmenite.

[5] Described by Janovsky and in Dana's "System of mineralogy," p. 239. Not to be confounded with iserine (Dana, op. cit., p. 219), which is referred to ilmenite.

[6] Janovsky, J. V., Über Niobit und ein neues Titanat von Isergebirge: Sitzungsb. Akad. Wiss. Wien, vol. 80, Math. naturw. Kl. (1), 1880, p. 39.

It is of a brown color, but pellucid and honey-yellow in thin lamellæ. Dana[1] states with regard to Janovsky's iserite—

> Groth (Z. Kryst., V, 400) justly remarks that the mineral is not far from the ferruginous rutile called "nigrine," and that a more exact determination as to form, homogeneity, etc., is needed to prove its independent character. If it is an independent species, the name is an unfortunate one, as tending to confusion with the distinct iserin, also called iserite.

Titanyl titanate or rutile.—The fourth mineral of this group is too well known to require extended description. It is tetragonal, $c=0.6442$, forms distorted twins like tapiolite, and has a density of 4.2. The interpretation of the composition of rutile as given by Brögger and Prior is as titanyl metatitanate $(TiO)\ (TiO_3)$.

Stannyl stannate or cassiterite.—Cassiterite, or stannyl metastannate, is also well known. It is tetragonal, $c=0.6723$, forms distorted twins, and has a density of 6.9.

Ferrous stannate.—Ferrous stannate, $Fe(SnO_3)$, not known in a pure state, is assumed to enter into the composition of some Mexican cassiterites to a considerable extent. It is probably present, though generally in small amounts, in nearly all cassiterites. Its properties are, of course, unknown.

Summary.—To better show the relationships of these chief primary compounds, their essential data, as given in the previous paragraphs, are brought together in the table below:

Properties of chief primary compounds.

Composition.	Formula.	Density.	Crystallography.
Ferrous columbate	$Fe(CbO_3)_2$	5.05?	Tetragonal, distorted twin, $c=0.6354$.
Ferrous tantalate	$Fe(TaO_3)_2$	7.85?	Tetragonal, distorted twin, $c=0.6522$.
Ferrous titanate	$Fe(TiO_3)_2$	5.±.25	Tetragonal, twinned, $c=0.64$.[a]
Titanyl titanate	$(TiO)\ (TiO_3)$	4.2	Tetragonal, distorted twin, $c=0.6442$.
Stannyl stannate	$(SnO)\ (SnO_3)$	6.9	Tetragonal, distorted twin, $c=0.6723$.
Ferrous stannate	$Fe(SnO_3)$	....	

[a] Like rutile.

MINOR PRIMARY COMPOUNDS.

In addition to these chief primary compounds it is necessary to assume the existence of several minor primary compounds in order to explain the composition of all the members of the rutile group. These have not as yet been found in nature either as pure compounds or as present to any great extent in isomorphous mixtures. Consequently their properties are entirely unknown, but their close chemical relationship can be seen by comparison of their formulas with those of type compounds such as $Fe(TaO_3)_2$ or $(SnO)(SnO_3)$. In the following list these minor primary compounds are given the highest percentages of their occurrence in any of the minerals herein described, as calculated by the methods used in this paper.

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[1] System of mineralogy, 5th ed., Appendix 3, 1884, p. 105.

Occurrence of minor primary compounds.

Formula.	Composition.	Maximum percentage of occurrence in natural minerals.
$Zn(AsO_3)_2$	Zinc arsenate	11.6
$Zn(SnO_3)$	Zinc stannate	8.6
$Fe(AsO_3)_2$	Ferrous arsenate	2.8
$Mn(TaO_3)_2$	Manganous tantalate	(See p. 20.)
$(SnO)(TaO_3)$	Stannyl tantalate; presence doubtful	(See p. 20.)
$(TiO)(VO_3)_2$	Titanyl vanadate; presence suggested	(See p. 26.)

ISOMORPHOUS RELATION OF PRIMARY COMPOUNDS.

In this paper I have regarded minerals as isomorphous if they possess very similar geometric form and close analogy in chemical composition, and if they form mixed crystals resembling in form those of the end members.

The first of the above three requirements is very well satisfied by this group of chief primary compounds in so far as data concerning them are available, as is shown by the summary of the properties of the compounds in the table just given. The close agreement of the values of the tetragonal *c* axes and the further evidence of the common occurrence of distorted twins is very suggestive of the close geometrical relation between the compounds.

The second requirement, close analogy in chemical composition, is not so readily disposed of, chiefly because of the incompleteness of the existing knowledge of the chemistry of such compounds as are under discussion. No difficulty has been met, but it must be admitted that some of the propositions advanced are only theoretical conceptions, though nothing has been so far brought against them and their validity is generally acknowledged.

The acids which are considered as isomorphous are as follows:

Columbic acid, $H_2(CbO_3)_2$, forming columbates.
Tantalic acid, $H_2(TaO_3)_2$, forming tantalates.
Metatitanic acid, $H_2(TiO_3)$, forming metatitanates.
Metastannic acid, $H_2(SnO_3)$, forming metastannates.
Metarsenic acid, $H_2(AsO_3)_2$, forming metarsenates.[1]

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[1] The relative instability of the metarsenates is probably overcome in the Mexican cassiterites (see p. 36) by the "mass action" of the predominant metastannates, $R_2(SnO_3)$.

The isomorphous relation of columbic and tantalic acids is too well known to require any further comment. The same relation has been proved for several compounds of titanium and tin, as, for example, for salts of the type $R'_2M''''F_6$, where M'''' represents Ti or Sn. Ouvrard[1] showed the isomorphous relation of the salts $Ti_2Na(PO_4)_3$ and $Sn_2Na(PO_4)_3$. The relation of tin to columbium and tantalum still remains to be proved, but the isomorphous relation of stannates to columbates and tantalates has been assumed in explaining the composition of a number of minerals. The relation of metarsenic acid to the other acids mentioned above is purely theoretical. The bases which combine with the acids to form the compounds whose admixture produces the minerals of the rutile group are Fe'', Zn'', Mn'', $(TiO)''$, and $(SnO)''$. The relationship of the titanyl group $(TiO)''$ to the stannyl group $(SnO)''$ is similar to that of the acids and hardly needs further comment. It is only necessary to see whether Fe'' and $(TiO)''$ can be considered isomorphous, but I have not been able to find any satisfactory evidence on this question. Such a relation seems very probable and has been assumed by numerous writers, but it remains to be proved.

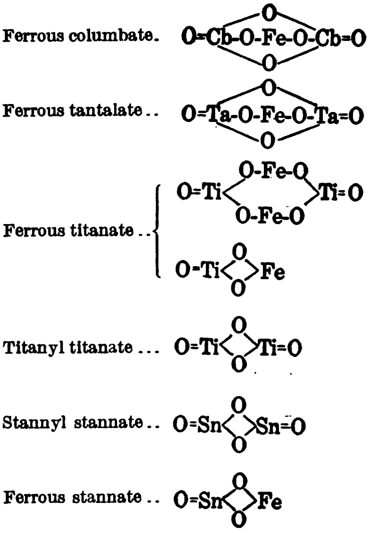

FIGURE 1.—Structural formulas for chief primary compounds of the rutile group.

That the isomorphous relationships of the bases and acids, as here given, are real and do occur in nature can only be shown by a consideration of the evidence as found in the natural occurrences of these minerals. A series of chemical salts in which these isomorphous relations can be traced may have been prepared and described, but I was not able to find any such descriptions in the literature. The evidence for a chemical analogy in these compounds can not, therefore, be considered definitely proved if the natural occurrences, which are, of course, the very ones for which the relationships are to be proved, are omitted. The evidence is largely theoretical, but at least no negative evidence has so far been brought to bear.

The formulas of the chief primary compounds may be expressed structurally in a form which at once suggests their very close chemical similarity.[2] These are shown in figure 1, the type structure being taken from Brögger's paper. In the first formula proposed for ferrous titanate the formula is doubled, as in this form the close relationship to ferrous columbate and ferrous tantalate is better shown.

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[1] Compt. Rend., vol. 111, 1890, p. 178.

[2] It must be remembered that no claim is made that these structural formulas actually represent the composition of the minerals. They do, however, show that analogies exist in the structure of these compounds, and for this reason they serve a very useful purpose.

The third requirement of the isomorphous relation, namely, ability to form mixed crystals, can not be demonstrated on artificial preparations, as knowledge of these compounds, produced artificially, is very small. The natural occurrences, however, afford plenty of evidence of such isomorphous mixing.

Original occurrences of all the primary minerals and of their various mixtures have been found in quartz-feldspar rocks of the pegmatite type. Tapiolite, "mossite," and cassiterite are typically found in pegmatite. Rutile is only rarely found in pegmatite; Brögger[1] states that he has never observed rutile in granitic pegmatites of south Norway. However, Watson and Taber, in describing the rutile deposits of Virginia,[2] speak of its occurrence in a "coarse-granined feldspar-quartz-hornblende rock" whose textural relations "over many parts of the rock mass [are] similar to those of a coarse pegmatitic granite." Further, "no evidence has been developed from either the field or the laboratory study for regarding the rutile as of secondary or subsequent origin." Rutile is also mentioned as an original constituent of the large pegmatite dike at Baringer Hill, Llano County, Tex.[3] The minerals here considered as forming an isomorphous group have therefore the further common bond that they have been found in a similar rock, namely, a quartz-feldspar or granitic pegmatite. Of the minerals here considered as simply isomorphous mixtures of the primary compounds, ilmenorutile, strüverite, and probably ainalite are all found in granitic pegmatites.

ISOMORPHOUS MIXTURES OF ESSENTIALLY TWO[4] OF THE PRIMARY COMPOUNDS.

FERROUS COLUMBATE AND FERROUS TANTALATE.

The isomorphous relations of ferrous columbate and ferrous tantalate have already been stated (p. 11). It was, in fact, an isomorphous mixture of these two compounds in approximately the proportion 1:1 which Brögger described as "mossite."

The analysis given by Brögger of "mossite" from Moss, Norway, is given below.

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[1] Die Mineralien der südnorwegischen Granit-Pegmatit-gänge. I. Niobate, Tantalate, Titanate, and Titaniobate: Videnskabs-Selskabets Skrifter.—Math. naturw. Kl., 1906, no. 6.

[2] Watson, T. L., and Taber, Stephen, The Virginia rutile deposits: Bull. U. S. Geol. Survey No. 430, 1910, pp. 200-213.

[3] Hess, F. L., Minerals of the rare-earth metals at Baringer Hill, Llano County, Tex.: Bull. U. S. Geol. Survey No. 340, 1908, p. 292.

[4] A third compound is occasionally present in minute quantity.

Analysis and ratios of "mossite" from Norway.

	Per cent.	Ratio.
Cb_2O_5	82.92 {31	0.116
Ta_2O_5	52	.118
SnO_2	.18	.001
FeO	16.62	.231
	99.72	

The ratios show that this mineral consists of—

0.5 part, or 0.2 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.
116 parts, or 39.2 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
118 parts, or 60.6 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.

Brögger's "mossite" is therefore a columbium-bearing tapiolite rather than a distinct species, and it would have been better if the name had not been proposed. It is hoped, as Hess and Wells[1] state, that the "custom of proposing names for unknown extrapolated members of a mineral series will not become general," and therefore the name "mossite" should be dropped, as it is believed that the material from Moss, Norway, is not entitled to specific distinction from tapiolite, being in fact only a columbic tapiolite.

Two analyses by Rammelsberg (Nos. 11 and 12 on p. 734 of Dana's System of Mineralogy) of tapiolite, or the so-called ixiolite, from Skogböle, Finland, gave the following results:

Analyses of ixiolite from Skogböle.

	1	2
Ta_2O_5	63.58	69.97
Cb_2O_5	19.24	[a] 12.26
SnO_2	1.70	2.94
FeO	9.19	14.83
MnO	5.97	
Ign	.23	
Total	99.91	100.00

[a] Including 1 per cent TiO_2, according to Dana.

Considering the 14.83 per cent FeO+MnO in the second analysis as FeO (justifiable because of the closeness of the molecular weights of FeO and MnO) and not considering the presence of titanium, the folowing ratios are obtained from the above analyses:

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[1] Hess, F. L., and Wells, R. C., An occurrence of strüverite: Am. Jour. Sci., 4th ser., vol. 31, 1911, p. 432.

Ratios of analyses of ixiolite from Skogböle.

	1		2	
Ta_2O_5	0.144	.216	0.158	.204
Cb_2O_5	.072		.046	
SnO_2	.011		.019	
FeO	.128	.212	.206	
MnO	.084		....	

From these ratios the composition of the samples of ixiolite is found to be as shown below.

No. 1 consists of—

72 parts, or 24.3 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
144 parts, or 74.0 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
5.5 parts, or 1.7 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.

No. 2 consists of—

46 parts, or 15.6 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
158 parts, or 81.5 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
9.5 parts, or 2.9 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.

An analysis of tapiolite from Sukula, Finland, by Rammelsberg, after the tetragonal character of the mineral had been established, is as follows:

Analysis and ratios of tapiolite from Sukula, Finland.

	Per cent.	Ratio.	
Ta_2O_5	73.91	0.167	.209
Cb_2O_5	11.22	.042	
SnO_2	.48	.003	
FeO	14.47	.201	.212
MnO	.81	.011	
	100.89		

The ratios show that the composition of this "tapiolite" is as follows:

1.5 parts, or 0.4 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.
42 parts, or 14.1 per cent, of ferrous columbate $Fe(CbO_3)_2$.
167 parts, or 85.5 per cent, of ferrous tantalate $Fe(TaO_3)_2$—tapiolite.

Two analyses of tapiolite from Custer City, S. Dak., are given by Headden.[1] They are very similar and are made on like material, so that the discussion of one of them will suffice. The results, with the ratios calculated therefrom, are here given. The density of this material is 7.22.

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[1] Headden, W. P., Mineralogical notes, No. III: Proc. Colorado Sci. Soc., vol. 8, 1906, p. 167

Analysis and ratios of tapiolite from South Dakota.

	Per cent.	Ratio.
Ta_2O_5	78.61	0.178 } .194
Cb_2O_5	4.29	.016
FeO	16.85	.234
SnO_2	.07	
Cassiterite	.31	
WO_3	.11	
TiO_2	Trace.	
	100.24	

The above ratios indicate that this tapiolite is composed of:

16 parts, or 5.6 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
178 parts, or 94.4 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.

The excess of FeO remaining must be ascribed to impure material or to some error in the analysis.

The tapiolite from Topsham, Maine, described by Warren,[1] would seem to contain a small amount of ferrous columbate, judging from the value of the density 7.67–7.68, that for tapiolite being 7.85.

The summary of the isomorphous mixtures of ferrous columbate and ferrous tantalate given below shows readily the variation in the proportions in which the two compounds have been found in nature.

Isomorphous mixtures of ferrous columbate and ferrous tantalate.

Described by—	Locality.	Ferrous columbate.	Ferrous tantalate.
		Per cent.	*Per cent.*
Brögger	Moss, Norway	39.2	60.6
Rammelsberg	Skogböle, Finland (1)	24.3	74.0
Do	Skogböle, Finland (2)	15.6	81.5
Do	Sukula, Finland	14.1	85.5
Headden	Custer City, South Dakota	5.6	94.4

As the maximum percentage of ferrous columbate so far found in nature reaches only 39.2 per cent, the objection to considering "mossite" a well-established species is seen to be valid.

FERROUS TANTALATE AND STANNYL STANNATE (TAPIOLITE AND CASSITERITE).

An analysis of tapiolite (skogbölite) from Skogböle by A. Nordenskiöld gave the following results:

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[1] Warren, C. H., Mineralogical notes: 4. Crystallized tapiolite from Topsham, Maine: Am. Jour. Sci., 4th ser., vol. 6, 1898, p. 121.

Analysis and ratios of tapiolite from Skogböle.

	Per cent.	Ratio
Ta_2O_5	84.44	0.191
Cb_2O_5	....	....
SnO_2	1.26	.008
FeO	13.41	.186 } .199
MnO	.96	.013
CuO	.14	....
CaO	.15	....
	100.36	

From the ratios, the composition is found to be as follows:

4 parts, or 1.2 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.
191 parts, or 98.8 per cent, of ferrous tantalate, Fe(TaO_3)$_2$—tapiolite.

It is interesting to note that Rammelsberg[1] gives three analyses of "tantalite" from Kimito, Finland, that contain respectively 6.81, 9.67, and 9.14 per cent of SnO_2. Though it is not possible to decide whether the material analyzed was tantalite or tapiolite, I believe it is more probably the latter. If this belief is correct, the samples present an additional instance of the isomorphism of tapiolite and cassiterite.

An analysis of supposed ixiolite from Wodgina in western Australia gave Simpson[2] the results shown in the table below. The mineral occurs in "indistinct crystalline aggregates," and though its identification as a tetragonal mineral is therefore not determined, Simpson regards it as related to the ixiolite from Finland. Its density is 7.36.

Analysis and ratios of ixiolite (?) from Australia.

	Per cent.	Ratio.
Ta_2O_5	70.49	0.159 } .188
Cb_2O_5	7.63	.029
SnO_2	8.92	.059
MnO	10.87	.153 } .172
FeO	1.34	.019
CaO	.42	....
MgO	.37	....
Ign	.18	....
	100.22	

From the above ratios the ixiolite (?) can be deduced to be of the composition shown below, the small amount of iron present being taken with the manganese. As can be seen from the ratios the

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[1] Rammelsberg, C. F., Handb. Mineralchemie, 1860, p. 391.

[2] Simpson, E. S., Further occurrences of tantalum and niobium in western Australia: Proc. Australian Assoc. Adv. Sci., 1909, vol. 12, 1910, p. 310.

$(MnO+FeO)$ is insufficient to take up all the $(Ta_2O_5+Cb_2O_5)$, so that, assuming accuracy of the analysis, it becomes necessary to assume the presence of the group (SnO) $(TaO_3)_2$. On this basis the ratios indicate:

29 parts, or 9.9 per cent, of $Mn(CbO_3)_2$.
143 parts, or 74.0 per cent, of $Mn(TaO_3)_2$.
16 parts, or 9.6 per cent, of (SnO) $(TaO_3)_2$.
21.5 parts, or 6.5 per cent, of (SnO) (SnO_3).

Assuming, however, that the $(Mno+FeO)$ exactly balances the $(Ta_2O_5+Cb_2O_5)$, as would happen with only a slight change in the analytical figures, the composition of the sample can be expressed more simply as:

29 parts, or 9.8 per cent, of $Mn(CbO_3)_2$.
159 parts, or 81.3 per cent, of $Mn(TaO_3)_2$.
29.5 parts, or 8.9 per cent, of (SnO) (SnO_3).

Either interpretation agrees with the analysis and both are in consonance with the character of the compounds propounded as forming, either singly or in isomorphous mixture, the several members of the rutile group. It is uncertain whether the mineral here described belongs to this group or to the orthorhombic columbite-tantalite group. If it is a member of this group, the discussion of it should also be placed under the heading "Isomorphous mixtures of more than two of the primary compounds." On account of the uncertainty as to whether it really belongs anywhere in the group no special emphasis is laid on the predominance of MnO replacing FeO. Should it be definitely determined that the mineral is tetragonal, like rutile, and not orthorhombic, the list of chief primary compounds would have to be increased by the addition of manganous tantalate, $Mn(TaO_3)_2$ and that of the minor primary compounds by the addition of manganous columbate, $Mn(CbO_3)_2$.

A cassiterite with nearly 9 per cent Ta_2O_5 was described from Finland and named ainalite by A. E. Nordenskiöld. Its analysis is given below in the first column and repeated in the second column, with the iron oxide given as FeO. The ratios are given in the third column.

Analysis and ratios of ainalite from Finland.

	Per cent.	Per cent.	Ratio.
SnO_2	88.95	88.95	0.589
Ta_2O_5	8.78	8.78	.020
Fe_2O_3	2.04	....	....
FeO	....	1.84	.026
CuO	.78	.78	....
	100.55	100.35	

The ratios indicate the following composition:

291.5 parts, or 88.3 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.
20 parts, or 10.4 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
6 parts, or 1.3 per cent, of ferrous stannate, $Fe(SnO_3)_2$.

Several other cassiterites are given as containing from 2 to 5 per cent tantalic acid, but their analyses are too imperfect to warrant further discussion.

A cassiterite from Mecklenburg, N. C., gave Headden[1] the results shown in the table below. The density is 6.77.

Analysis and ratios of cassiterite from Mecklenburg, N. C.

	Per cent.	Ratio.
SnO_2	95. 18	0. 630
FeO	1. 11	. 015
Ta_2O_5	3. 82	. 009
	100. 11	

From the above values the composition of the cassiterite is deduced to be as follows:

9 parts, or 4.6 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
6 parts, or 1.3 per cent, of ferrous stannate, $Fe(SnO_3)$.
312 parts, or 94.1 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

A cassiterite from the Etta mine, South Dakota, likewise analyzed by Headden gave the following percentages and ratios. Its density is 6.62. In Headden's analysis the iron is reported as 1.80 per cent Fe_2O_3, and this has been changed to the corresponding percentage of FeO.

Analysis and ratios of cassiterite from South Dakota.

	Per cent.	Ratio.
SnO_2	94. 36	0. 625
FeO	1. 62	. 023
Ta_2O_5	2. 42	. 005
SiO_2	1. 00	....
	99. 58	

From the above values the composition of this cassiterite is expressed as:

5 parts, or 2.5 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
18 parts, or 4.1 per cent, of ferrous stannate, $Fe(SnO_3)$.
303.5 parts, or 93.3 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

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[1] Headden, W. P., Mineralogical notes, No. III: Proc. Colorado Sci. Soc., vol. 8, 1906, p. 167.

Both these cassiterites approach ainalite, which contains a little more Ta_2O_5 than either of the American cassiterites.

A cassiterite from the Greenbushes, Australia, contains, according to Simpson,[1] 1.76 per cent Ta_2O_5 and 0.61 per cent iron oxide, etc.

The following summary of the isomorphous mixtures of tapiolite and cassiterite seems to indicate that their miscibility with each other is very slight. Further examination of natural specimens will probably show, however, that their miscibility is complete.

Isomorphous mixtures of tapiolite and cassiterite.

Analyst.	Locality.	Ferrous tantalate (tapiolite).	Stannyl stannate (cassiterite).
		Per cent.	*Per cent.*
Nordenskiöld	Skogböle, Norway	98.8	1.2
Rammelsberg	Kimito, Finland	93 to 90	6.81 to 9.67
Simpson[a]	Wodgina, West Australia	[b] 91.1	8.9
Nordenskiöld	Finland	10.4	88.3
Headden	Mecklenburg, N. C	4.6	94.1
Headden	Etta mine, S. Dak	2.6	[c] 93.3

[a] See p. 19 for description of this mineral.

[b] Includes 81.3 per cent manganous tantalate ($MnTaO_3$) and 9.8 per cent manganous columbate ($MnCbO_3$).

[c] There is also present in the mineral 4.1 per cent ferrous stannate.

STANNYL STANNATE AND TITANYL TITANATE (CASSITERITE AND RUTILE).

A peculiar occurrence of elongated twins, reacting for both titanium and tin, was described by M. von Miklucho-Maclay.[2] If this occurrence is confirmed, the mineral may represent an admixture of rutile and cassiterite, a possibility entirely in accord with the facts.

TITANYL TITANATE (RUTILE) AND FERROUS TITANATE.

Three analyses of rutile from Graves Mountains, Ga., described as large black-brown prisms, pure and homogeneous, are given [3] in columns 1, 2, and 3 of the following table.

The average of these three analyses is shown in column 4, and by changing the values for Fe_2O_3 into the corresponding figures for ferrous oxide,[4] the results in column 5 are obtained, from which the ratios (under 6) are calculated.

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[1] Op. cit., p. 310.

[2] Rutil und Zinnstein im Greifensteiner Granit (Ehrenfriedersdorf): Neues Jahrb., vol. 2, 1885, p. 88.

[3] Pfeil, Karl, Ueber die Aufschliessung der Silikate und anderer schwer zersetzbarer Mineralien mit Borsaure-anhydrid: Centralbl. Min., Geol. u. Pal., 1902, p. 143.

[4] The assumption that the iron is really present as FeO and not as Fe_2O_3 depends, of course, on the supposed purity of the material.

Analyses and ratios of rutile from Georgia.

	Analyses.			Average.	Average.	Ratio.
	1	2	3	4	5	6
TiO_2	97.64	97.22	97.52	97.46	97.46	1.218
Fe_2O_3	2.61	2.62	2.64	2.62	....	....
FeO	....	....	....	....	2.36	.033
	100.25	99.84	100.16	100.08	99.82	

From these values the composition is found to be:

33 parts, or 5.0 per cent, of ferrous titanate, $FeTiO_3$.
593 parts, or 95.0 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

An analysis of a jet-black rutile from St. Peter's Dome, Colo., gave[1] the results shown in the following table. The crystal form is that of rutile with dominant {111}; twinning not mentioned. Measurements "give results with the reflection goniometer agreeing closely with the calculated angles for this species [rutile]". Considering the SiO_2 and H_2O as extraneous, the TiO_2 and FeO give the ratios shown below:

Analysis and ratios of rutile from St. Peter's Dome, Colo.

	Per cent.	Ratio.
TiO_2	94.93	1.187
FeO	3.77	.052
SiO_2	1.37	....
H_2O	.71	....
	100.78	

The composition of this rutile is, therefore:

52 parts, or 8.0 per cent, of ferrous titanate, $FeTiO_3$.
567.5 parts, or 92.0 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

The density of the sample is 4.288, which is somewhat higher than that of rutile (4.2).

An iron-black rutile in distorted pyramids {111}, but not twinned, from West Cheyenne Canyon, El Paso County, Colo., gave the analysis shown below.[2] Recalculating the iron reported as Fe_2O_3 to FeO, the analysis is as given in the second column; the ratios obtained from these figures are given in the third column.

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[1] Smith, W. B., Mineralogical notes No. III: Proc. Colorado Sci. Soc., vol. 2, 1887, p. 175.

[2] Genth, F. A., and Penfield, S. L., Contributions to mineralogy, No. 54, with crystallographic notes: Am. Jour. Sci., 3d ser., vol. 44, 1892.

Analysis and ratios of rutile from El Paso County, Colo.

	Per cent.	Per cent.	Ratio.
TiO_2	91.96	91.96	1.149
SnO_2	1.40	1.40	.009
Fe_2O_3	6.68	....	....
FeO	....	6.01	.083
	100.04	99.37	

From the values of the ratios, the composition of this sample is as follows:

4.5 parts, or 1.3 per cent, of stannyl stannate (SnO) (SnO_3)—cassiterite.
83 parts, or 12.8 per cent, of ferrous titanate, Fe (TiO_3).
533 parts, or 85.9 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

The density of the sample is given as 4.249, which seems to be a little low.

A nigrine from Bernau, Bavaria, is described by Rammelsberg[1] who gives the following analysis (first column), which is repeated in the second column with the ferric iron oxide changed to the corresponding amount of ferrous oxide. The density of this material is 4.41.

Analysis and ratios of nigrine from Bavaria.

	Per cent.	Per cent.	Ratio.
TiO_2	89.49	89.49	1.118
Fe_2O_3	11.03	....	
FeO	....	9.93	$\left.\begin{matrix}.110\\.011\end{matrix}\right\}.121$
MgO	.45	.45	
	100.97	99.87	

The ratios indicate the following composition:

121 parts, or 18.8 per cent, of ferrous titanate, Fe (TiO_3).
498.5 parts, or 81.2 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

Rammelsberg[2] mentions two other analyses of nigrine. The first (from Ohlapian, Siebenburgen, Transylvania) has, according to Klaproth, the composition shown below in the first column. With the iron and manganese oxides changed to the bivalent condition, the analysis is repeated in the second column. The density is given as 4.445 (Klaproth) and as 4.4–4.5 (Breithaupt). The mean value is 4.45.

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[1] Rammelsberg, C. F., Handb. Mineralchemie, Zweite Aufl., I. Theil, 1875, p. 169.
[2] Rammelsberg, C. F., Handb. Mineralchemie, 1860, p. 1009.

Analysis and ratios of nigrine from Transylvania.

	Per cent.	Per cent.	Ratio.
TiO_2	84	84.0	1.05
Fe_2O_3	14		
FeO		12.6	.17
Mn_2O_3	2		
MnO		1.8	.03
	100	98.4	

The ratios may be interpreted as follows:

20 parts, or 31 per cent, of ferrous titanate, Fe (TiO_3).
42.5 parts, or 69 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

The second analysis given is by Müller, who analyzed nigrine from Bariern with the results shown below:

Analysis and ratios of nigrine from Bariern.

	Per cent.	Ratio.
TiO_2	86.2	1.08
FeO	14.2	.20
	100.4	

This would correspond to a mixture in the following proportions:

20 parts, or 30 per cent, of ferrous titanate, Fe (TiO_3).
44 parts, or 70 per cent, of titanyl titanate (TiO) (TiO_3)—rutile.

The composition of the two samples is very close but the density given for the last sample is high, namely 4.56. It is not improbable that some columbium and tantalum were present in each sample, which would account for the rather high densities.

The analyses of iserite from Iser, Bohemia, given by Janovsky, are repeated in the first and second columns below, the average being given in the third column and the ratios in the fourth.

Analysis and ratios of iserite from Bohemia.

	Per cent.	Per cent.	Per cent.	Ratio.
TiO_2	70.03	68.99	69.51	0.869
FeO	28.77	28.57	28.67	.426
MnO	Not det.	1.41	1.41	
MgO	Not det.	.32	.32	
Cb_2O_5	Not det.	.44	.44	.002
Ta_2O_5				
		99.73	100.35	

In calculating the ratios from the average analysis, the (MnO + MgO) are included with the FeO, and the mixture of ($Cb_2O_5 + Ta_2O_5$) is arbitrarily considered as pure Cb_2O_5.

The composition of iserite is from these analyses calculated to be as follows:

2	parts, or 0.6 per cent, of ferrous columbate, Fe $(CbO_3)_2$.
424	parts, or 64.0 per cent, of ferrous titanate, Fe (TiO_3).
222.5	parts, or 35.4 per cent, of titanyl titanate, (TiO) (TiO_3)—rutile.

Considering the formula of rutile in the form here given, the mineral under consideration contains an excess of ferrous titanate. The density of iserite is given as 4.52. Knowing the density of ferrous columbate[1] (at least approximately) and also that of rutile, the density of pure ferrous titanate may be calculated. Taking the density of rutile as 4.2 and that of the ferrous columbate present in this iserite as 6.5 (Brögger gives 6.45 for his "mossite" with Cb : Ta = 1 : 1), there is obtained for the density of ferrous titanate the value 4.7. This is, however, lower than the values obtained from nigrine, as is shown in the table below.

The isomorphous mixtures of titanyl titanate (rutile) and ferrous titanate are shown in the following table:

Mixtures of titanyl titanate (rutile) and ferrous titanate.

Locality.	Ferrous titanate.	Titanyl titanate (rutile).	Density.	Calculated density of ferrous titanate.
	Per cent.	*Per cent.*		
Georgia	5.0	95.0	....	....
St. Peters Dome, Colo	8.0	92.0	4.288	5.3
El Paso County, Colo	12.8	85.9	4.249	5.1
Bavaria	18.8	81.2	4.41	5.3
Transylvania	31.0	69.0	4.45	5.0
Barien	30.0	70.0	4.56	5.4
Iser, Bohemia	64.0	35.4	4.52	4.74

All the calculations of the density of ferrous titanate, except the last, give values of 5 or over. The last, the value obtained from iserite, supposedly of correct determination, gives a figure much lower than any of the others. The density of ferrous titanate, therefore, can not be given any more definitely than 5 ±.25.

TITANYL TITANATE (RUTILE) AND TITANYL VANADATE (?).

The possible occurrence of titanyl vanadate as an additional member of the minor primary compounds is indicated by a rutile from Roanoke County, Va. This rutile is said to carry 5 percent

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[1] The small amount present would not have an effect greater than that due to experimental error.

V_2O_5 and a qualitative test, made at the suggestion of Mr. F. L. Hess, showed a decided reaction for vanadium. The presence of this vanadium can be most readily explained by the assumption of the presence of the molecule $(TiO)(VO_3)_2$ in isomorphous mixture with $(TiO)(TiO_3)$.

STANNYL STANNATE (CASSITERITE) AND FERROUS STANNATE.

The only analyses of iron-rich cassiterites that I could find are those made by Genth[1] on Mexican tinstones. Through the courtesy of Mr. F. L. Hess, of the Geological Survey, I was enabled to examine cassiterites similar to those described by Genth. On examining crushed fragments under the microscope the material appeared to be homogeneous, and no admixed ferric oxide could be seen. I therefore believe that iron is a fundamental ingredient of at least some of these ferriferous cassiterites and, assuming that it is present in the ferrous condition, instead of in the ferric, as reported by Genth, I have recalculated his iron determinations and given them here in the corresponding ferrous state. Not all Genth's analyses are reproduced, for many are very similar and one of such suffices. The numbers of the analyses are those given by him.

Analyses of ferriferous cassiterites from Mexico.

	I_b	II	V_a	V_b
SnO_2	92.84	93.98	86.99	86.81
FeO	3.71	5.06	10.40	11.46
As_2O_5	Trace.	....	Trace.	....
CuO	Trace.	....	.11	....
SiO_2	2.70	.23	.57	.52
Ign	.34	.24	.20	.34
	[a] 99.59	[a] 99.51	[a] 98.27	[a] 99.13

[a] If the iron is actually present as FeO the number giving the "ignition" value should be increased by the amount of oxygen required to oxidize the ferrous iron. This would raise the total values to 99.96, 100.02, 99.31, 100.28, respectively.

The ratios deduced from the above analyses, neglecting CuO, SiO_2, and ignition, are as follows:

Ratios of ferriferous cassiterites from Mexico.

	I_b	II	V_a	V_b
SnO_2	0.615	0.622	0.576	0.575
FeO	.051	.070	.144	.159

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[1] Genth, F. A., Proc. Am. Philos. Soc., vol. 24, 1887, p. 26.

These ratios give the following composition of the four samples:

I_b consists of {51 parts, or 11.8 per cent, of ferrous stannate, $Fe(SnO_3)$.
282 parts, or 88.2 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

II consists of {70 parts, or 15.8 per cent, of ferrous stannate, $Fe(SnO_3)$.
276 parts, or 84.2 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

V_a consists of {144 parts, or 32.3 per cent, of ferrous stannate, $Fe(SnO_3)$.
216 parts, or 67.7 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

V_b consists of {159 parts, or 36.1 per cent, of ferrous stannate, $Fe(SnO_3)$.
208 parts, or 63.9 per cent, of stannyl stannate $(SnO)(SnO_3)$—cassiterite.

The last two samples, isomorphous mixtures of ferrous stannate, $Fe(SnO_3)$, and stannyl stannate $(SnO)(SnO_3)$, include an amount of the first-named salt equal to about one-third of their total composition.

Two more analyses of these ferriferous cassiterites, shown below, have as their most noteworthy feature the presence of small amounts of As_2O_5. In certain other varieties the amount of As_2O_5 is even greater than in the two analyses quoted below. With the analyses are given the ratios deduced from them.

Analyses and ratios of cassiterite from Mexico.

	VI		IV	
	Per cent.	Ratio.	Per cent.	Ratio.
SnO_2	92.26	0.611	92.09	0.610
FeO	4.12	.057	4.90	.068
As_2O_5	1.25	.006	2.11	.009
ZnO	.57	.007		
CuO	Trace.			
SiO_2	.44		.66	
Ignition	.26		.07	
	98.90		99.83	

In considering the composition of these two cassiterites, it becomes necessary to admit two compounds hitherto not found in the list of primary compounds. The new compounds are zinc arsenate $ZnO.As_2O_5$, and ferrous arsenate, $FeO.As_2O_5$, or, as written in conformity with the other salts of these minerals, $Zn''(AsO_3)_2$ and $Fe''(AsO_3)_2$. These compounds I could not find described in the literature, but from a consideration of other series of polymorphic forms of the general rutile group formula, $R''(RO_3)''$, the validity of the assumption that $Zn''(AsO_3)_2$ and $Fe''(AsO_3)_2$ are isomorphously related to $Fe''(TiO_3)_2$ and its related compounds is strongly indicated by the composition of such minerals as lewisite and derbylite.

The two cassiterites whose analyses were just given are shown by the ratios to be made up of the substances and in the proportions shown below.

VI consists of
6 parts, or 1.9 per cent, of zinc arsenate, Zn $(AsO_3)_2$.
57 parts, or 12.9 per cent, of ferrous stannate, Fe (SnO_3).
277 parts, or 85.2 per cent, of stannyl stannate, (SnO) (SnO_3)—cassiterite.

IV consists of
9 parts, or 2.8 per cent, of ferrous arsenate, Fe $(AsO_3)_2$.
59 parts, or 13.5 per cent, of ferrous stannate, Fe $(SnO_3)_2$.
271 parts, or 83.7 per cent, of stannyl stannate, (SnO) (SnO_3)—cassiterite.

The isomorphous mixtures of stannyl stannate (cassiterite) and ferrous stannate, as developed in the preceding pages, are summarized in the following table:

Mixtures of ferrous stannate and stannyl stannate (cassiterite).

Analyst.	Locality.	Ferrous stannate.	Stannyl stannate (cassiterite).
		Per cent.	*Per cent.*
Nordenskiöld [a]	Finland	1.3	[b] 88.3
Headden [a]	North Carolina	1.3	[c] 94.1
Headden [a]	Etta Mine, South Dakota	4.1	[d] 93.3
Genth	Mexico	11.8	88.2
Do	do	12.9	[e] 85.2
Do	do	13.5	[f] 83.7
Do	do	15.8	84.2
Do	do	32.3	67.7
Do	do	36.1	63.9

[a] Described on p. 21.
[b] This mineral also includes 10.4 per cent of tapiolite.
[c] This mineral also includes 4.6 per cent of tapiolite.
[d] This mineral also includes 2.6 per cent of tapiolite.
[e] This mineral also includes 1.9 per cent of zinc arsenate.
[f] This mineral also includes 2.8 per cent of ferrous arsenate.

ISOMORPHOUS MIXTURES OF MORE THAN TWO OF THE PRIMARY COMPOUNDS.

The mixtures of more than two of the primary compounds include strüverite, ilmenorutile, and some of the Mexican cassiterites analyzed by Genth.

STRÜVERITE.

Strüverite was described by Prior and Zambonini in 1908 and, as they state at the end of their paper, the name strüverite is proposed "for those members of the series which are rich in tantalic acid." These minerals are regarded "as essentially solid solutions of the tapiolite or mossite molecule $Fe[(Ta, Nb)O_3]_2$ with the rutile molecule

$TiO.TiO_3$." Such a conception, however, entirely ignores the slight but constant excess of FeO in the analyses. The tetragonal crystals of strüverite resemble those of rutile in habit and in their angular values. Prior and Zambonini state: "Of frequent occurrence are crystals elongated along the edge $s:\acute{s}=[(111):(1\bar{1}1)]$; most of these appear to be twins on a face of the form {101}, like the well-known twins of ilmenorutile, tapiolite, and mossite, and also of rutile from certain localities." The value deduced for the *c* axis is 0.6456. (Compare the values given on p. 12.)

The following are the analytical figures given by Prior and Zambonini for strüverite from Italy:

Analyses and ratios of strüverite from Italy.

	Analysis.		Average.	Ratio.	
	Per cent.	*Per cent.*	*Per cent.*		
TiO_2	41.09	41.32	41.20	0.515	
Cb_2O_5	46.94	46.98	23.48	.088	.141
Ta_2O_5			23.48	.053	
FeO	11.15	11.62	11.38	.158	.171
MnO	Trace.	....	Trace.	....	
CaO	.51	....	.51	.009	
MgO	.17	....	.17	.004	
			100.22		

Inspection of the ratios shows that there is an excess of FeO over the amount required to combine with the Cb_2O_5 and Ta_2O_5. If, however, we assume the presence of sufficient ferrous titanate to take up all the remaining FeO, the interpretation of the above average analysis becomes simple and accurate. The ratios show, in fact, that the material analyzed is an isomorphous mixture of the four minerals in the proportions shown below.

88 parts, or 29.9 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
53 parts, or 27.4 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
17 parts, or 2.6 per cent, of ferrous titanate, $Fe(TiO_3)$.
249 parts, or 40.1 per cent, of titanyl titanate, $(TiO)(TiO_3)$—rutile.

For an isomorphous mixture of the proportions shown above, the calculated composition is given below in comparison with the strüverite analysis. The agreement of the calculated values with those in the analysis is very close, so that the explanation offered is consistent. The direct comparisons with the analytical figures clearly bring out the correctness of the view here proposed.

Two determinations of the density of strüverite give 5.54 and 5.59, from which a mean value of 5.57 may be taken.

Calculated percentages of strüverite from Italy compared with analysis.

	Calculated.	Analysis.
TiO_2	41.41	41.20
Cb_2O_5	23.62	23.48
Ta_2O_5	23.54	23.48
FeO	11.43	11.38
MnO	....	Trace.
CaO	....	.51
MgO	....	.17
	100.00	100.22

An occurrence of strüverite from the Etta mine, South Dakota, has been described by Hess and Wells.[1] According to their analysis, the South Dakota mineral, unlike the Italian strüverite, fits the definition of strüverite given by Prior and Zambonini.

The analysis of strüverite from South Dakota and the ratios calculated therefrom are given below. The close relation in crystalline form of this mineral to rutile is described in the paper referred to.

Analysis and ratios of strüverite from South Dakota.

	Per cent.	Ratio.	
TiO_2	49.0	0.613	.622
SnO_2	1.3	.009	
FeO	7.3	.101	.101
Ta_2O_5	35.7	.081	.106
Cb_2O_5	6.7	.025	
	100.0	....	

The ratios approximate the formula $FeO.(Ta,Cb)_2O_5.6H_2O$, but there is no warrant for assuming the existence of such a compound. The composition may be interpreted according to the following tabulation, which shows the mineral to be an isomorphous mixture of the primary compounds of the rutile group, tapiolite and rutile largely predominating.

25 parts, or 8.4 per cent, ferrous columbate, $Fe(CbO_3)_2$.
81 parts, or 41.4 per cent, ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
306.5 parts, or 48.8 per cent, titanyl titanate (TiO) (TiO_3)—rutile.
4.5 parts, or 1.4 per cent, stannyl stannate (SnO) (SnO_3)—cassiterite.

This strüverite is the only mineral of this entire group containing Cb, Ta, Fe, and Ti in quantity in which no ferrous titanate is present.

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[1] Hess, F. L., and Wells, R. C., An occurrence of strüverite: Am. Jour. Sci., 4th ser., vol. 31, 1911, p. 432.

That the percentages of the primary compounds closely represent the true composition of the mineral can be shown in another way, namely, by calculating back the percentage values of the different oxides and comparing them with the analytical figures. The values obtained should, of course, agree exactly or nearly so[1] with the analytical figures from which the percentages of the primary compounds were obtained. The calculated composition is compared with the analytical figures in the table below:

Calculated percentages of strüverite from South Dakota compared with analysis.

	Calculated.	Analysis.
TiO_2	49. 0	49. 0
SnO_2	1. 3	1. 3
FeO	7. 3	7. 3
Ta_2O_5	35. 8	35. 7
Cb_2O_5	6. 6	6. 7
	100. 0	100. 0

A black rutile or nigrine from South Dakota with a brilliant and metallic luster was described by Headden and Pirsson.[2] The streak was grayish black, the hardness 6, and the density 5.294. The measurements of the crystals agreed well with the angles of rutile, but the value given for the density is entirely too high for a rutile of the composition given by Headden and Pirsson. As their material was similar to that analyzed and described by Hess and Wells, their analytical figures are doubtless entirely wrong for the TiO_2.

Their analyses gave the values shown under 1 and 2, but no ratios are deduced because the value given for TiO_2 is considered erroneous.

Analyses of supposed rutile from South Dakota.

	1	2
TiO_2	90. 78	90. 80
SnO_2	1. 32	1. 38
FeO	8. 10	7. 92
MnO	Trace.	Trace.
	100. 20	100. 10

That the mineral described by Headden and Pirsson is similar to that analyzed by Wells is shown by comparison of the two analyses, in which the constituents other than $TiO_2+Cb_2O_5+Ta_2O_5$ agree closely. The densities of the two minerals also correspond well.

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[1] Slight differences will be found because of impurities in the mineral which are given in the analysis but are not figured in the ratios, and because the calculations are not carried to a sufficient number of decimals.

[2] Headden, W. P., and Pirsson, L. V., On black rutile from the Black Hills: Am. Jour. Sci., 3d ser., vol. 14, 1891, p. 249.

Comparison of analyses of South Dakota mineral.

	Average of analyses 1 and 2.	Wells's analysis.	
TiO_2	90.79	49.0	91.4
Cb_2O_5		6.7	
Ta_2O_5		35.7	
SnO_2	1.35	1.3	
FeO	8.01	7.3	
MnO	Trace.	....	
	100.15	100.0	

Average density of mineral analyzed by Headden and Pirsson, 5.294.
Density of mineral analyzed by Wells, 5.25.

ILMENORUTILE.

Ilmenorutile is found in tetragonal crystals similar to rutile in angles and frequently twinned after (101), being often elongated parallel to the edge $(111):(1\bar{1}1)$.

Ilmenorutile from the Ilmen Mountains was analyzed by Prior. His results and ratios are given below.[1] The density of his material is 5.14.

Analysis and ratios of ilmenorutile from the Ilmen Mountains.

	Per cent.	Ratio.	
TiO_2	53.04	0.663	
Cb_2O_5	21.73	.081	.114
Ta_2O_5	14.70	.033	
FeO	10.56	.147	
CaO	Trace.	....	
	100.03	....	

The ferrous iron is again in excess of that required for the columbate and tantalate, and the interpretation of the analysis shows four of the primary mineral species to be present in quantity. The composition is indicated to be as follows:

33 parts, or 5.0 per cent, of ferrous titanate, $FeTiO_3$.
81 parts, or 27.5 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
33 parts, or 17.0 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
315 parts, or 50.5 per cent, of titanyl titanate, $(TiO)(TiO_3)$—rutile.

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[1] An earlier analysis given by G. T. Prior (Mineralog. Mag., vol. 15, 1908, p. 86) is excluded here because in it the $Cb_2O_5+Ta_2O_5$ were not separated.

The calculated values for the composition, as given in the table above, are shown with the analysis repeated in the table below.

Calculated percentages of ilmenorutile from the Ilmen Mountains compared with analysis.

	Calculated.	Analysis.
TiO_2	53.13	53.04
Cb_2O_5	21.66	21.73
Ta_2O_5	14.61	14.70
FeO	10.60	10.56
CaO	....	Trace.
	100.00	100.03

An analysis of ilmenorutile from Evje Kirschspiel, in Saetersdal, as described by Brögger[1] and corrected by Prior[2] gave the following results:

Analysis and ratios of ilmenorutile from Saetersdal.

	Per cent.	Ratios.	
TiO_2	54.50	0.681	
SiO_2	.23	......	
Cb_2O_5	33.02	.124	.125
Ta_2O_5	.43	.001	
FeO	11.58	.161	
MgO	.04	......	
CaO	.22	......	
	100.02		

Here, again, the ferrous iron is in excess and it becomes necessary, as suggested by Brögger, to consider the admixture of the molecule $FeTiO_3$. The composition of the mineral can then be expressed as follows:

36 parts, or 5.5 per cent, of ferrous titanate, $Fe(TiO_3)$.
124 parts, or 42.1 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
1 part, or 0.5 per cent, of ferrous tantalate, $Fe(TaO_3)_2$—tapiolite.
322.5 parts, or 51.9 per cent, of titanyl titanate, $(TiO)(TiO_3)$—rutile.

A comparison of the calculated composition, as given above, with the analysis, is shown in the following table, in which is also given the nearly identical analysis of ilmenorutile from Ansel, near Tvedestrand, given by Brögger and corrected by Prior:

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[1] Videnskabs-Selskabets Skrifter.—Math. naturw. Kl., 1906, no. 6.

[2] Prior, G. T., op. cit., p. 86.

Calculated percentages compared with analyses of ilmenorutile.

	Calculated.	Ilmenorutile from Evje.	Ilmenorutile from Ansel.
TiO_2	54.69	54.50	54.50
Cb_2O_5	33.23	33.02	33.49
Ta_2O_5	.44	.43	....
FeO	11.64	11.58	11.68
SiO_2	....	.23	.05
MnO	....	....	Trace.
MgO	....	.04	Trace.
CaO	....	.22	.28
	100.00	100.02	100.00

Ilmenorutile from Iveland, Norway, was also analyzed by Prior. Tantalum could not be detected, so no admixture of tapiolite is present. The low summation is ascribed to a probable slight loss of columbium.

Analysis and ratios of ilmenorutile from Iveland.

	Per cent.	Ratio.
TiO_2	54.57	0.682
Cb_2O_5	32.15	.120
FeO	12.29	.170
CaO	.11	....
MgO	Trace.	....
	99.12	

It can at once be seen that the ferrous iron is greatly in excess of the columbic oxide, so that a relatively large amount of ferrous titanate must be present. The ratios lead to the following interpretation:

120 parts, or 41.1 per cent, of ferrous columbate, $Fe(CbO_3)_2$.
50 parts, or 7.7 per cent, of ferrous titanate, $Fe(TiO_3)$.
316 parts, or 51.2 per cent, of titanyl titanate, $(TiO)(TiO_3)$—rutile.

A comparison with the analysis of the values calculated from this composition is given below:

Calculated percentages compared with analysis of ilmenorutile from Iveland.

	Calculated.	Analysis.
TiO_2	55.20	54.57
Cb_2O_5	32.41	32.15
FeO	12.39	12.29
CaO	....	.11
MgO	....	Trace.
	100.00	99.12

ARSENICAL CASSITERITE.

Three analyses of the Mexican cassiterites[1] show them to be practically free from iron, but to contain considerable As_2O_5 and ZnO. In fact, the ZnO is always in molecular excess to the amount of As_2O_5 required to form $Zn(AsO_3)_2$, so that the small amounts of ZnO(+FeO) left over are combined with sufficient tin to form the compound $Zn(SnO_3)$, whose acceptance in the list of primary compounds is as well grounded as is that of $Fe(SnO_3)$.

Analyses of cassiterite from Mexico.

	VIII	IX	X
SnO_2	92.50	89.90	93.13
FeO	.20	.09	.18
ZnO	1.89	2.43	2.71
CuO	.16	.20	.09
As_2O_5	4.56	5.80	3.18
SiO_2	.24	.55	.43
Ign	.26	.40	.32
	99.81	99.37	100.04

Ratios of analyses of cassiterite from Mexico.

	VIII		IX		X	
SnO_2	0.613		0.595		0.617	
FeO	.003	.028	.001	.034	.003	.037
ZnO	.023		.030		.033	
CuO	.002		.003		.001	
As_2O_5	.020		.025		.014	

If the FeO and CuO are treated as ZnO, these ratios indicate the following composition for the above three samples:

VIII consists of
20 parts, or 6.2 per cent, of zinc arsenate, $Zn(AsO_3)_2$.
8 parts, or 3.0 per cent, of zinc stannate, $Zn(SnO_3)$.
302.5 parts, or 90.8 per cent, of stannyl stannate, $(SnO)(SnO_3)$—cassiterite.

IX consists of
25 parts, or 7.8 per cent, of zinc arsenate, $Zn(AsO_3)_2$.
9 parts, or 3.1 per cent, of zinc stannate, $Zn(SnO_3)$.
293 parts, or 89.1 per cent, of stannyl stannate, $(SnO)(SnO_3)$—cassiterite.

X consists of
14 parts, or 4.2 per cent, of zinc arsenate, $Zn(AsO_3)_2$.
23 parts, or 8.6 per cent, of zinc stannate, $Zn(SnO_3)_2$.
297 parts, or 87.2 per cent, of stannyl stannate, $(SnO)(SnO_3)$—cassiterite.

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[1] Analyzed by Genth, op. cit.

One analysis shows proportionately a large amount of As_2O_5, but the molecular amount of $ZnO+FeO$ still exceeds the amount required to form $(Zn, Fe)\,(AsO_3)_2$. This analysis and the ratios derived from it are shown below:

Analysis of cassiterite from Mexico.[a]

	Per cent.	Ratio.
SnO_2	84.30	0.558
FeO	1.39	.019
ZnO	2.96	.037
CuO	Trace.	
As_2O_5	10.34	.045
SiO_2	.30	
Ign	.57	
	99.86	

[a] Genth's analysis VII b.

The composition of this sample is expressed by the following tabulation:

37 parts, or 11.6 per cent, of zinc arsenate, $Zn(AsO_3)_2$.
8 parts, or 2.4 per cent, of ferrous arsenate, $Fe(AsO_3)_2$.
11 parts, or 2.5 per cent, of ferrous stannate, $Fe(SnO_3)$.
273.5 parts, or 83.5 per cent, of stannyl stannate, $(SnO)\,(SnO_3)$—cassiterite.

CONCLUSION.

It has been shown that chemically all the minerals here described may be considered as isomorphous members of a series consisting of several distinct compounds or as mixtures of two or more of those compounds. All the mixtures have the same or nearly the same crystallographic values (tetragonal, $c=0.64$ approximately), and nearly all possess the peculiar distorted twinning. That no morphotropic series is at hand is shown by the constancy of the crystallographic axis c, and I believe that formulas such as $FeO.(Ta,Cb)_2O_5.4TiO_2$ for strüverite and $FeO.(Cb,Ta)_2O_5.5TiO_2$ for ilmenorutile, as suggested by Prior and Zambonini, are incorrect, and that the writers who have proposed them fail to consider the obvious isomorphous relations of the much simpler (in composition) primary compounds. Prior and Zambonini state, however, that "closer agreement between the amounts found and calculated are obtained when we assume an admixture of the molecule $FeTiO_3$ (as suggested by Brögger) or of $FeTi_2O_5$, molecules such as may be present in the ferriferous rutiles. On this assumption, the formula of ilmenorutile from the Ilmen Mountains would be $3.5[FeO.(Cb\frac{5}{7}, Ta\frac{2}{7})_2O_5.5TiO_2]+FeTi_2O_5$, and of that from Iveland $2.4[FeO.Cb_2O_5.5TiO_2]+FeTi_2O_5$." These formulas, however, contain compounds the existence of neither of which ($FeO.Cb_2O_5.5TiO_2$, $FeTi_2O_5$) has been demonstrated. The evidence of the mutual isomorphous mixing in varying proportions of the primary constituents is so strong that I believe the simpler explanation here offered to be nearer the true one. I would therefore propose that of the different minerals and mineral mixtures comprising the rutile group, as I define it, the only names[1] that should be kept up as distinct mineral species are the three following:

Tapiolite, $Fe(TaO_3)_2$ or $FeO.Ta_2O_5$.
Rutile, $(TiO)(TiO_3)$ or TiO_2.
Cassiterite, $(SnO)(SnO_3)$ or SnO_2.

In addition, the name ilmenorutile will serve, as a subspecies, to indicate those mixtures in which Fe, Ta, Cb, and Ti are present in quantity. Brögger's "mossite" is then only a columbium tapiolite. When the pure or nearly pure (tetragonal) iron columbate is found in nature, then a new name will be appropriate and necessary. Similarly, the compounds $FeTiO_3$ and $FeSnO_3$, when found in nature in a pure or nearly pure condition will be entitled to distinct new mineral names.

Nigrine and iserite are only iron rutile, ainalite is a tantalum cassiterite, and strüverite[2] the same as ilmenorutile. If it seems desirable, the various ilmenorutiles can be called columbium ilmenorutile, tantalum ilmenorutile, titanium ilmenorutile, iron ilmenorutile, and tin ilmenorutile, depending on which of these elements predominates in the composition of specimens.

The several cassiterites from Mexico analyzed by Genth can be called, to distinguish them from pure cassiterite, iron cassiterite, arsenic or arsenical cassiterite, zinc cassiterite, etc. Such a system of nomenclature at once defines a variety—for example, tantalum cassiterite means cassiterite containing tantalum. To give a new name for every variety of a known mineral would lead to such a multiplicity of names that any systematic scheme of nomenclature would be hopeless. The system here proposed is elastic enough to permit nearly all new finds to be referred to it.

A name should not be put forward—or if proposed should not be accepted—for a known mineral in which a small amount of some other element is present, particularly where the presence of that element is due to isomorphous replacement. If a rutile contains several per cent of iron in combination, it should not be given a distinct name (like nigrine), but should be called what it really is, an iron rutile, or a ferriferous rutile. If a calcite contains a little cobalt, it should not be called cobaltocalcite, but simply a cobalt calcite. Indiscriminate use of distinct names for mere varieties or for certain isomorphous mixtures opens up the possibility of an infinite number of names which would in time so complicate the science of mineralogy as to make it unfit for practical service.

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[1] As additional members of this group, which rank as well-defined species, are to be added zircon, thorite, polianite, plattnerite and perhaps others. See footnote on p. 9.

[2] Certainly the Italian strüverite has no claim for specific identity distinct from ilmenorutile.

The mineral names used in this discussion which it is believed have no claim for recognition as distinct mineral species and the descriptive terms proposed to replace them are as follows:

Mossite	columbium tapiolite.
Nigrine and iserite	iron rutile.
Ainalite	tantalum cassiterite.
Strüverite[1]	ilmenorutile.

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[1] I here mean the strüverite from Italy. The mineral from South Dakota would be called tantalum ilmenorutile.

BARBIERITE, MONOCLINIC SODA FELDSPAR.

The existence of a monoclinic dimorphous form of albite isomorphous with orthoclase, was long ago suggested, but the presence of soda in orthoclase analyses has generally been otherwise explained, most commonly by granting the presence of albite or an orthoclase. In a recent paper by Barbier and Prost[1] analyses are given of feldspars in which the cleavage angle varies but a few minutes from 90° and in which soda is present in molecularly greater amount than the potash. The maximum soda content is reached in a feldspar from Kragerö, Norway, in which only 1.15 per cent K_2O was found.

Prof. Barbier was kind enough to send me some slides of the feldspar from Kragerö which, according to his analysis, consists essentially of the soda compound. One of the slides, a basal section giving parallel extinction and appearing to be uniform, was uncovered and the feldspar washed free from Canada balsam. The mineral was then immersed in an oil with a refractive index of 1.530, and it was seen that the index of the mineral was considerably lower than that of the oil. If the orientation of the mineral is the same as that of orthoclase a basal section would yield values for α and for γ. As these were both found to be decidedly lower than 1.530, the section can not be albite.[2] Unfortunately the very small section was accidentally lost before its soda content could be verified microchemically.

Microscopic examination by Prof. Barbier showed that with one exception albite was not present in his specimens, and consequently the existence of a monoclinic soda feldspar isomorphous with orthoclase must be admitted. I propose to call this particular monoclinic soda feldspar barbierite, in honor of Prof. Barbier, who is a member of the faculty of the University of Lyon, France. He has recently published, in addition to the paper above cited, an article on the feldspar group in which he gives a definite chemical difference between orthoclase and microcline.[3] Further analyses of soda-rich orthoclases are given by him in a later paper.[4] The feldspar from Kragerö is nearly pure barbierite.

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[1] Barbier, Ph., and Prost, A., Sur l'existence d'un feldspath sodique monoclinique, isomorphe de l'orthose: Bull. Soc. chim., 1908, III, p. 894.

[2] For albite, $\alpha = 1.529$, $\gamma = 1.539$.

[3] Barbier, Ph., Recherches sur la composition chimique des feldspaths potassiques: Bull. Soc. franç. minéral., vol. 31, 1908, p. 152.

[4] Barbier, Ph. and Gonnard, F., Analyses de quelques feldspaths français: Bull. Soc. franç. mineral., vol. 33, 1910, p. 81.

Angel[1] recently described a soda-bearing monoclinic sanidine, which contains 4.92 per cent Na_2O and 6.75 per cent K_2O. The cleavage angle (001) : (010) is 90° 01′ and the extinction on (001) is parallel. The feldspar is monoclinic and consists approximately of equal parts of the isomorphous orthoclase and barbierite. In his paper Angel gives several references to earlier publications on feldspars which undoubtedly contain barbierite in isomorphous admixture.

This opportunity may be taken to call attention to an error in the first paper of Prof. Barbier referred to. The locality of one of the specimens is given as Francheville le Bas (Rhone). The correct locality is Orlienas (Rhone). Prof. Barbier asked me to call attention to this error in locality.

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[1] Angel, Franz, Ueber einen Natronsanidin von Mitrowitza: Neues Jahrb. für Min., Beil.-Band, vol. 30, 1910, p. 254.

CRYSTALLIZED TURQUOISE FROM VIRGINIA.

INTRODUCTION.

A sample of a bright blue mineral, from near Lynch station, Campbell County, Va., was brought to the Geological Survey for identification by Mr. J. H. Watkins. As a few preliminary tests failed to identify the mineral with any known species, a complete study of it was undertaken. The results obtained show that the supposed new mineral is identical with turquoise. The chief interest, however, lies in the fact that this turquoise is well crystallized, so that it was possible to measure several of the minute crystals and determine thereby the crystallography of the mineral. I am deeply indebted to Mr. Watkins for his kindness in furnishing the material (now deposited in the United States National Museum, catalogue No. 86990), and in allowing this description to be published. A photograph of the specimen is shown in Plate I, *A*.

The matrix of the specimen consists of irregular fragments of glassy quartz of various sizes, cemented together by thin layers of turquoise crystals. On one side of the specimen the turquoise forms a drusy, botryoidal layer, cavernous in texture and including many small irregular fragments of the glassy quartz. The turquoise, with its many included quartz fragments, polishes well and makes a very handsome ornamental stone. The spheres which form the botryoidal surface bristle with minute crystals and average about 2 or 3 millimeters in diameter. The individual crystals rarely are as much as a third of a millimeter long, being usually smaller and much thinner.

GENERAL DESCRIPTION.

The turquoise is blue in color and has a vitreous luster. Cleavage is present, possibly in two directions. The mineral is brittle and has a hardness of about 5, though the minute size and brittleness of the crystals make it difficult to determine the hardness with accuracy. The density, determined with a pycrometer on the powdered sample analyzed, is 2.816, which, when corrected for the 12.57 per cent insoluble material (mostly quartz) present,[1] gives for the pure turquoise the value 2.84.

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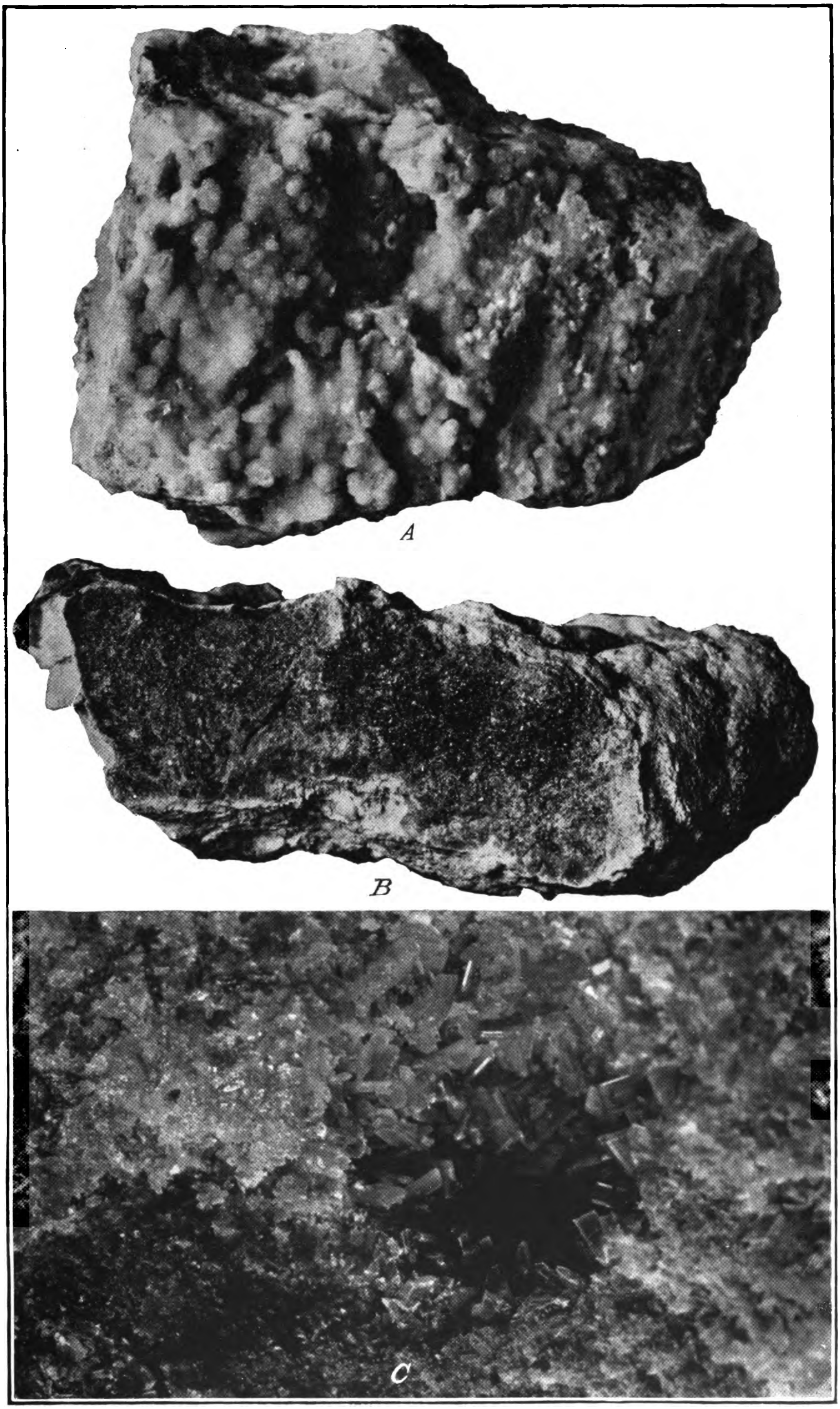
[1] See analysis, p. 45.



A. CRYSTALLIZED TURQUOISE FROM VIRGINIA, NATURAL SIZE.

B. VARISCITE NODULE FROM UTAH, NATURAL SIZE. ON THE LEFT, AN AGGREGATE OF CRYSTALS; ON THE RIGHT, THE ORDINARY COMPACT PHASE.

C. VARISCITE CRYSTALS IN A CAVITY OF AGGREGATE OF CRYSTALS, FROM UTAH. ENLARGED 6 DIAMETERS.

Examined under the microscope, the crystals are clear and transparent and the material is very pure. Pleochroism is distinct, from colorless to pale bluish. Extinction is inclined on all sections, and, as verified by the measurements, the crystals are triclinic. Nōne of the sections showed a good interference figure, though such as were seen indicated biaxiality. One cleavage plate, possibly parallel to *M* $(1\bar{1}0)$, showed extinction of 12° against the vertical direction and 12° against the other edge $(1\bar{1}0 \wedge 0\bar{1}1$?). A different cleavage section of a rhombic shape showed extinction values of 5° and 34° respectively, but the orientation of this piece could not be determined. The double refraction of the mineral is high, about 0.04. The refractive indices are about: $\alpha = 1.61$, $\gamma = 1.65$. Lacroix[1] gives the value 1.63 for the mean index.

CRYSTALLOGRAPHY.

The crystals are very minute and so closely grown together that it was almost impossible to obtain any suitable for measurement. One complete crystal was found that gave fairly good reflections, and the measurements made from it were verified by those obtained on a second less perfect crystal. A third incomplete one also yielded a few measurements. The dimensions of the first two crystals were as follows:

Crystal No. 1, 0.27 mm. high (*c* axis), 0.32 mm. wide (*b* axis).
Crystal No. 2, 0.32 mm. high (*c* axis), 0.40 mm. wide (*b* axis), 0.12 mm. thick (*a* axis).

The crystals are triclinic and in angles very near to those of chalcosiderite. The angular values of turquoise and chalcosiderite are so close that the crystallographic elements of chalcosiderite have been adopted for those of turquoise, as the crystals of the latter mineral are poorly adapted for accurate measurements. In fact, were it not for a knowledge of the crystallography of chalcosiderite (isomorphous with turquoise, as is shown in this paper in the discussion of chemical composition), it is doubtful if the orientation of the turquoise crystals could have been interpreted.

The values for turquoise are, then, as follows: $a : b : c = 0.7910 : 1 : 0.6051$; $\alpha = 92° 58'$, $\beta = 93° 30'$, $\gamma = 107° 41'$.

Forms: *b* {010}, *a* {100}, *m* {110}, *M* $\{1\bar{1}0\}$, *k* $\{0\bar{1}1\}$.

The comparison of the measured angles with the calculated ones[2] are shown below.

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[1] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 529.

[2] These calculated values are, with one exception, taken from the values calculated for chalcosiderite by Maskelyne, Jour. Chem. Soc., vol. 28, 1875, p. 586.

Comparison of measures and calculated angles, turquoise.

Angle.	Measured.			Calculated.
	Crystal No. 1.	Crystal No. 2.	Crystal No. 3.	
	° ′	° ′	° ′	° ′
$1\bar{1}0 \wedge 100$	45 12	....	....	44 50
$100 \wedge 110$	31 14	31 28	31 25	31 10
$110 \wedge \bar{1}10$	104 14	....	104 03	104 00
$110 \wedge 010$ [a]	37 28	38 39	....	40 54
$0\bar{1}1 \wedge \bar{1}10$	107 42	105 15	....	105 36
$0\bar{1}1 \wedge 100$	....	95 33	....	95 45
$0\bar{1}1 \wedge 110$	....	110 00	....	109 36
$0\bar{1}1 \wedge 010$ [a]	....	117 26	....	119 19

[a] The faces of {010} gave very poor reflections.

The habit of the crystals is shown in figure 2.

The forms *a* {100} and *M* {1$\bar{1}$0} are large and striated vertically, *a* generally more striated than *M*. The prism *m* {110} is small sized and striated parallel to the edge (110): (0$\bar{1}$1). Between *m* and *k* {011} lies an undetermined small face very much striated. The clinopinacoid *b* {010} is very small and uneven and gives a very poor reflection. The dome *k* {0$\bar{1}$1} is the only terminal face definitely determined and is strongly striated on crystal No. 1, though perfectly smooth and yielding an excellent reflection on crystal No. 2. It may be that the face *k* on crystal No. 2 is a cleavage face, as an easy cleavage parallel to this dome was noted by Maskelyne on chalcosiderite.

The pointed appearance of the minute crystals is due to the sharpness of the upper right-hand corner where the intersection of *a*{100} and *k*{0$\bar{1}$1} yields an acute point.

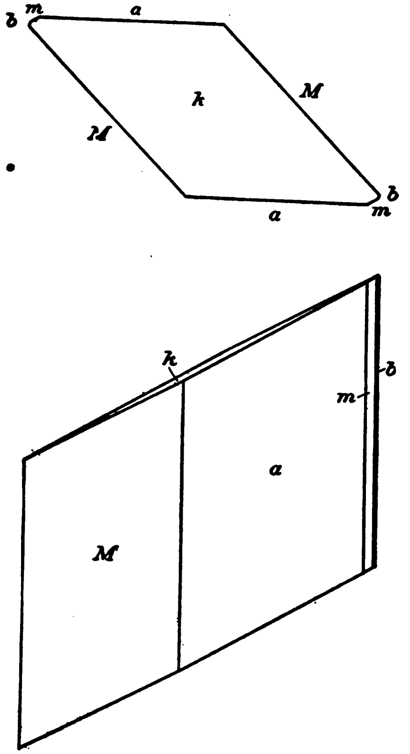

FIGURE 2.—Turquoise crystal. *b*{010},*a*{100},*m*{110}, *M*{1$\bar{1}$0},*k*{0$\bar{1}$1}.

CHEMICAL COMPOSITION.

Abundant material was available for the analysis, which was made on carefully selected pieces free from all impurities except the quartz. It was found that the mineral is insoluble in boiling hydrochloric acid, but that after gentle ignition (when it has turned brown) it is readily soluble in acids. The mineral does not lose any water below 200° and retains its blue color at that temperature. Between 200° and 650°, all the water is given off [1] and the mineral becomes greenish in color. On higher heating the greenish color changes to a brown. The mineral is infusible before the blowpipe, but becomes brown.

The average analysis is shown in the table below in the first column; in the second column is given the same analysis with the insoluble matter (quartz) deducted.

Analysis and ratios of turquoise.

	Analysis.	Analysis (insoluble matter deducted).	Ratio.	
P_2O_5	29.84	34.13	0.240	2.07 or 2
Al_2O_3	31.91	36.50	.357	3.09 or 3
Fe_2O_3	.18	.21	.001	....
CuO	7.87	9.00	.113	.97 or 1
H_2O	17.59	20.12	1.118	9.64 or 9
Insoluble matter	12.57	....	....	....
	99.96	99.96		

The formula derived from the ratios of the analysis is $CuO.3Al_2O_3.$-$2P_2O_5.9H_2O$. According to Penfield's suggestion [2] as to the relation of the hydroxyl groups, this formula can be interpreted as $CuOH.6[Al(OH)_2].H_5.(PO_4)_4$. I believe that this formula expresses the definite composition of turquoise and a comparison with other analyses shows that this formula is doubtless the correct one.

Among the best analyses of turquoise is that made by Penfield[2] on material from Lincoln County, Nev. This turquoise was "of exceptionally fine quality * * * very fine-grained, of a beautiful robin's-egg blue color, and broke with a smooth fracture * * * when examined under the microscope, the turquoise seemed to be perfectly uniform, showing no evidence of being made up of two substances * * * it acted somewhat on polarized light." Its density is given as 2.791.

In the following table are given the analysis of the turquoise from Virginia and Penfield's analyses of turquoise from Lincoln County, Nev. In the third column is shown the composition calculated for the formula proposed.

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[1] Nearly all the water is expelled below 400°.

[2] Penfield, S. L., On the chemical composition of turquoise: Am. Jour. Sci., 4th ser., vol. 10, 1900, p. 346.

Analyses of turquoise.

	Virginia.	Nevada.	Calculated for $CuO.3Al_2O_3$.-$2P_2O_5.9H_2O$.
P_2O_5	34.13	34.18	34.12
Al_2O_3	36.50	35.03	36.84
Fe_2O_3	.21	1.44	....
CuO	9.00	8.57	9.57
H_2O	20.12	19.38	19.47
Insoluble matter	....	.93	....
	99.96	99.53	100.00

The agreement of the three analyses is very close, so that the formula $CuO.3Al_2O_3.2P_2O_5.9H_2O$ expresses definitely the composition of this mineral.

Of the other analyses of turquoise, in which the purity of material is not so definitely known as in the two analyses just cited, only those given by Penfield [1] are quoted in the following table:

Analyses of turquoise.

	Calculated.	Persia. (Church.)	Russia. (Nicolajew.)	California. (Moore.)	New Mexico. (Clarke.)		
P_2O_5	34.12	32.86	34.42	33.21	31.96	32.86	28.63
Al_2O_3	36.84	40.19	[35.79]	35.98	[c] 39.53	36.88	37.88
Fe_2O_3	....	[a] 2.45	3.52	2.99	....	2.40	4.07
CuO	9.57	5.27	7.67	7.80	6.30	7.51	6.56
H_2O	19.47	19.34	18.60	19.98	19.80	19.60	18.49
Miscell	....	[b] 0.36	....	....	[d] 1.28	[e] 0.54	[f] 4.20
	100.00	100.47	100.00	99.96	98.87	99.79	99.83
Sp. gr	....	2.75	2.89	2.86	....	2.80	....

[a] Given as FeO. The figures are in better agreement with values calculated from formula if the iron is considered in the ferrous condition.

[b] MnO.

[c] Includes some Fe^2O^3.

[d] Insoluble, 1.15; CaO, 0.13.

[e] Insoluble, 0.16; CaO, 0.38.

[f] Insoluble.

The high alumina values may be partly accounted for by the admixture of a little aluminous rock. By considering some of the iron present as ferrous oxide, FeO, isomorphously replacing the CuO, the analyses agree very well with the values calculated for the composition.

Penfield's idea that the composition of the mineral should be expressed as $[Al(OH)_2, Fe(OH)_2, CuOH, H]_3PO_4$ can be more definitely fixed now, for the analysis of crystals of turquoise shows that the $Al(OH)_2$, $CuOH$, and H are present in fixed amounts, namely, in the proportions 6: 1: 5. Penfield's analysis agrees very closely with these figures.[1]

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[1] Loc. cit.

Crystallographic measurements have shown the apparent isomorphism of turquoise and chalcosiderite. The formula given for chalcosiderite is $CuO.3Fe_2O_3.2P_2O_5.8H_2O$, which differs from that proposed for turquoise only in containing one molecule less of water. From Maskelyne's[2] description of the material used for the analysis of chalcosiderite it seems probable that the sample was contaminated by a little andrewsite, limonite, and dufrenite, all of which contain less water[3] than chalcosiderite, so that the value he obtained is probably a little low. The correct formula for chalcosiderite should probably be written with $9H_2O$ instead of $8H_2O$, in which event the isomorphous character of this mineral with turquoise will be clearly brought out.

Turquoise.......... .$CuO.3Al_2O_3.2P_2O_5.9H_2O$, triclinic.
Chalcosiderite......$CuO.3Fe_2O_3.2P_2O_5.9H_2O$, triclinic.

SUMMARY.

In closing, the three main points developed in this paper may be briefly restated:

1. Turquoise is triclinic with the crystal form determined.
2. Turquoise has the definite composition $CuO.3Al_2O_3.2P_2O_5.9H_2O$.
3. Turquoise and chalcosiderite are isomorphous.

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[1] Penfield deduced the ratios 7: 1: 6 from his analyses, but 6: 1: 5 is still closer.

[2] Maskelyne, N. S., On andrewsite and chalcosiderite: Jour. Chem. Soc., vol. 28, 1875, p. 586.

[3] Andrewsite has 8.8 per cent, limonite 14.5 per cent, and dufrenite 10.5 per cent water; chalcosiderite has 15 per cent.

CRYSTALLIZED VARISCITE FROM UTAH.

INTRODUCTION.

The material on which the following descriptions are based was collected near Lucin, Utah, by Mr. Douglas B. Sterrett, of the United States Geological Survey. A part of the material consists of well-developed crystals, a form of occurrence so unusual for variscite that the identity of that mineral was not discovered until after detailed study. The quantity of material was sufficient to determine all the chief properties of the mineral, one of the most striking of which was brought out by Mr. Sterrett in heating a fragment of it before the blowpipe, for at a low temperature its vivid green color was changed readily to a deep lavender. The chemical study of the mineral was extended in order to find out if possible the cause of this change. The various properties of the lavender-colored variscite were studied, as well as those of the green mineral, in order to discover their relations. I wish to express my thanks to Mr. Sterrett for permission to describe this very interesting mineral and for his generosity in furnishing the material needed.

OCCURRENCE AND GEM QUALITY.

The following notes on the occurrence of the variscite near Lucin, Utah, and of the kind and quality of the gem stones procured are by Sterrett:[1]

> The variscite deposits, 5 miles northwest of Lucin, Utah, * * * are in the northern part of an irregularly shaped hill, called Utahlite Hill. Utahlite Hill is about 1 mile long in a northwest-southeast direction and about one-half mile wide. It has an elevation of about 5,000 feet above sea level and rises over 300 feet above the mesas and gentle slopes at its base, and about 500 feet above the railroad at Lucin. Four claims have been located and these are, in order from northwest to southeast, Utah Gem, Greenback Lode, Utahlite, and Protection Lode. * * *
>
> [The variscite deposits are] in and around small rocky summits standing above the rest of the hill. These summits have cavities and small caverns [in them] * * * resembling those made by wave action. They were probably formed on one of the shore lines of the former Lake Bonneville. The work done at the time of examination consisted of an open cut 50 feet long and 2 to 5 feet deep with several prospect pits.

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[1] Gems and precious stones: Mineral resources U. S. for 1910, U. S. Geol. Survey, 1912, pp. 894–896.

The rock in which the variscite occurs and which forms the crest of the hill is cherty or chalcedonic quartz, which contains inclusions of nodules and streaks of limestone. The limestone inclusions range up to a foot thick and in places are several feet long. The character of most of the rock is that of a hard breccia cemented together by silica. This breccia forms rough, rocky ledges and knobs rising from a few feet to 25 feet above the hill slopes. * * * Three of these knobs contain large quantities of variscite.

The variscite occurs in balls, nodules, and irregular masses in the chert. Veins of variscite are not common, but some with a northeast strike and northwest dip were seen. The nodules and balls of variscite range in size from a fraction of an inch to several inches across, and some of the segregations of variscite inclosing matrix are a foot across. The variscite fills fractured and brecciated zones in the rock, some of which it replaces, and it incloses other parts. The replacements are generally rounded, concretionary masses, often with banded concentric structure. The fragments of some of the brecciated rock, especially white quartz, that have been inclosed by and cemented with variscite, have remained angular and sharp. Some of the concretionary forms appear to grade from green variscite cores into the inclosing yellow, brown, gray, and white phosphatic and cherty minerals. There is considerable chalky mineral filling cavities in the variscite-bearing rock and coating the nodules and masses of variscite. A quantity of variscite pebbles and cobbles have been found in the cut in the loose detritus below the main outcrop on the Utahlite claim. These probably owe a large part of their rounded form to the nodular shape of the variscite in the original rock, but have also probably been rounded by water action on a former lake shore. The pebbles are coated with a white chalky substance, and have to be broken into before the presence or quality of the variscite can be determined.

* * * Both the variscite and the matrix minerals possess various shades of color, several of which are sometimes present in a single specimen. The different colors combined with the various markings and patterns due to the structure of the mineral and brecciation of the matrix furnish a large range in the types of stones that can be cut from the variscite. The variscite ranges in color from a very pale green through different shades of green to bright grass green. The matrix varies from white to gray, to yellow, to brown, and nearly to black.

The gems that can be cut from the variscite from the Edison and Bird mines range from large pure stones with light to dark green color through those with small quantities of matrix, to those in which the matrix predominates. The dark and bright green variscite is obtained in pieces that will cut into pure stones measuring more than an inch across, and paler-colored mineral will yield even larger pure stones. Some of the bright-green variscite is partly translucent, and thin pieces and small pebbles display their color well in the partially transmitted light. This is especially true of the coarser-grained, finely crystalline variscite. Specimens of matrix are obtained that will yield slabs 6 inches across, some of which show quite remarkable patterns and colors. One block of matrix found at this mine measures 4 to 6 inches in diameter and weighs several pounds. The whole mass is composed of variscite mottled with brown and white matrix. The pattern is the typical turtle-back, and the markings are coarser in some parts of the specimen than in others. The markings are due to rounded patches or nodules of pale to bright-green variscite, some of which are surrounded by rims of white or gray, and all filled in with purplish brown matrix. The brown matrix occurs only as an internodular filling, and the seams are rarely over a millimeter thick. Occasional larger patches of matrix occur where several seams meet around the variscite nodules. The rounded masses of variscite vary from a fraction of a millimeter to a centimeter in diameter. Other smaller pieces of mottled variscite have been found along with specimens of brown, gray, and white matrix, with practically the same texture. Some pieces of mottled matrix contain little if any variscite, but would itself cut into stones with the turtle-back markings.

Among other types of variscite matrix is that with bright grass-green variscite mottled with patches and cloud-like masses of lighter green material, or vice versa. Such matrix may contain seams and spots of white, gray, or yellowish mineral through it. A white quartz breccia cemented and filled in with bright green variscite is also a pleasing stone when cut, but is more difficult to polish because of the difference in hardness of the two minerals. The quartz occurs in sharp angular fragments, which are in excess of the variscite in some specimens, but generally less prominent.

The variscite and variscite matrix from this locality would yield very beautiful gems for the so-called barbaric jewelry. It is susceptible to nearly every form of cutting used with opaque gems, but on account of its comparative softness is not adapted to rough wear. For necklaces, pendants, brooches, pins, belt stones, etc., it is well suited. The especially bright colors of some of the variscite from this locality are rarely found in that from other places, and the variety of markings shown by the matrix is probably equal to any other material found.

GENERAL DESCRIPTION.

The material available for study consists of nodular aggregates of variscite, irregular in shape and of various dimensions. The deep green aggregates of crystallized mineral consist of tabular crystals, a few of which reach a millimeter in length. Their breadth is about half their length, and their thickness varies from about one-fourth of a millimeter to very thin plates. The coarser aggregates of variscite consist of well-developed crystals (Pl. I, *B*, *C*, p. 42), which are often nearly complete. The finer-grained material does not show such distinct crystals, and the very fine-grained compact mineral has more the appearance of a cryptocrystalline mass. Several small cavities in the coarse material were lined with projecting crystals which furnished good material for crystallographic study. The crystals are transparent and pale green when viewed under the microscope. A view of such a cavity enlarged six times is shown in Plate I, *C*.

OPTICAL PROPERTIES.

ORIENTATION AND PLEOCHROISM.

The crystallographic orientation was so chosen that the large, flat face of the crystals became the brachypinacoid *b* {010} and the striations on this face were placed vertically. Variscite being orthorhombic, these facts are sufficient to definitely orient the crystals so that the optical relations can be readily comprehended. The basal pinacoid, *c* {001}, was not observed on these crystals, and the macropinacoid, *a* {100}, is a rare form, seldom larger than a narrow face between the unit prisms m and m'''.

The optical relations were ascertained by studying the flat crystals and by means of two thin sections of the granular aggregate, which were carefully prepared without being subjected to any heat. If a section of the granular variscite be made in the ordinary manner, the heat employed in the operation is sufficient to change the green color of the mineral to deep lavender, with consequent changes in the various physical properties.

The extinction is parallel in all sections, and the mineral behaves optically in strict concordance with the orthorhombic symmetry of the crystals. The axial plane is parallel to the flat face *b* {010}, and the acute bisectrix is normal to the base *c* {001}, the obtuse bisectrix then being normal to *a* {100}. The mineral is positive, so that the acute bisectrix, identical in direction with the crystallographic axis *c*, is the axis of minimum velocity of light. The optical relationship can therefore be expressed in the conventional form as follows:

$$\begin{aligned} a &= X = \mathfrak{a} \\ b &= Y = \mathfrak{b} \\ c &= Z = \mathfrak{c} \end{aligned}$$

The axial angle is large; 2E was measured as about 113°. Dispersion was not marked, and its kind could not be determined.

Viewed in transmitted light under the microscope, the crystals are colorless if very thin, or pale green if somewhat thicker. The coloring pigment is not uniformly distributed, but is generally arranged in irregular cloudlike areas. In a few slides the coloring seemed to be distributed in some relation to the shape of the crystals and was most intense near their edges.

The pleochroism is distinct, but slight. Its relation to the crystal directions is shown in the following scheme:

a (*X*) = colorless.
b (*Y*) = pale green.
c (*Z*) = pale green.

The weakness of the pleochroism is in striking contrast to that of the heated lavender-colored material in which, as is described on page 53, the pleochroism is strong.

REFRACTIVE INDICES.

The indices of refraction were measured by the method of oil immersion for γ and α. The values found are: $\gamma = 1.577$ and $\alpha = 1.547$. Therefore $\gamma - \alpha = 0.030$, which is very close to the average value (0.032) found by actual determination of the birefringence. This birefringence was measured accurately on the flat brachypinacoid, and the average value obtained is 0.032. The value was measured on 11 crystals, with the following results:

Birefringence ($\gamma-\alpha$) *measured on b* {*010*}.

Crystal No.	Thickness in millimeters.	Birefringence.
1	0.055	0.034
2	.044	.029
3	.042	.035
4	.070	.027
5	.051	.031
6	.051	.037
7	.066	.029
8	.055	.034
9	.042	.030
10	.053	.030
11	.047	.034
Average.	....	.032

As the value 0.032 is, of course, more accurate than the value 0.030 obtained by measuring the indices directly, the values of and α are each changed one unit so as to bring their difference in accord with the more accurately determined value of the birefringence, and are therefore taken as 1.578 and 1.546, respectively.

The value for β was found by measuring the difference of refraction ($\beta-\alpha$) in basal sections of the mineral. A thin section of the crystalline aggregates furnished basal and macropinacoid sections of the same thickness, so that the value ($\beta-\alpha$) could be determined by noting the interference colors (first order blue) on the basal sections and comparing them with the colors on sections showing the maximum birefringence. The value ($\beta-\alpha$) was thus found to be 0.010. Therefore $\beta=1.556$.

A section of a crystal that seemed to be nearly parallel to $a\{100\}$ showed a very large axial angle and a difference of refraction of about 0.020, which, for a section parallel to $a\{100\}$, should be 0.022.

A summary of the optical properties as determined follows:

Axial plane b (010). $Bx_a \perp c$ (001). Positive.
$\alpha=1.546$, $\beta=1.556$, $\gamma=1.578$.
$\gamma-\alpha=0.032$, $\gamma-\beta=0.022$, $\beta-\alpha=0.010$.

$$n=\frac{\alpha+\beta+\gamma}{3}=1.560.$$

STRUCTURE OF CRYSTALS.

An additional feature of considerable interest is the structure of the crystals. Although the material is well crystallized and the individual crystals sharply bounded by plane and brilliant surfaces, the interior of the crystals is, in most cases, crowded with a mass of small particles irregularly bounded and not in parallel position with the crystal itself. In some crystals these particles are absent; in others they are sparsely scattered. Still other crystals contain a vast number of these particles, generally closely aggregated. These aggregates are either irregular in shape and occupy the center of the crystal, or else they are so arranged as to correspond with the shape of the crystal itself. Such a regular grouping of these particles is shown in figure 3, which illustrates also the tabular habit of the variscite crystals. In figure 3 the brachypinacoid *b*{010} is drawn in front in order to show better the mode of distribution of the particles. These particles are in general irregular in shape, though occasionally a rectangular one can be noted in the mass. The particles still manifest themselves in the dehydrated lavender crystals and show no difference, except in their orientation and shape, from the rest of the crystal.

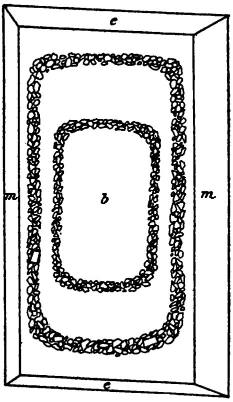

FIGURE 3.—Variscite crystal, showing regular grouping of small particles. *b* {010}, *m* {110}, *e* {012}. The brachypinacoid *b* {010} is drawn in ront.

PROPERTIES OF DEHYDRATED LAVENDER VARISCITE.

The very remarkable color change undergone by the mineral on dehydration at a relatively low temperature (below 160°) has a marked effect on its optical properties. The most striking change is in the pleochroism. The green crystals of variscite are only faintly pleochroic (colorless to pale green), whereas the lavender ones are strongly pleochroic with intense colors.

The optical orientation of these lavender-colored crystals could not be determined, though numerous attempts were made, both on loose crystals and on thin sections of the granular aggregate. The birefringence of the mineral has become so low that no definite results could be obtained when tests for axial angles were made. Both basal and brachypinacoidal sections seemed to show the emergence of a bisectrix with a very large axial angle, though, as stated, the results were inconclusive. It could, however, be easily seen that the optical orientation was changed. In the green crystals, viewed on the flat face *b*{010}, the vertical axis is a direction of minimum velocity, but on the lavender crystals this same direction is one of maximum velocity. Similarly, on basal sections the axis *b* is a direction of minimum velocity for the green crystals, whereas on the lavender ones the *b* axis is a direction of maximum velocity

The pleochroism of the lavender crystals is strong and very striking. All the colors are combinations of red and blue and are therefore rather hard to describe accurately. On crystals that are not too thin the colors are very intense and beautiful. The brachypinacoidal sections are strongly pleochroic, whereas basal sections hardly show any difference in shade in different directions. The colors observed may be described as follows:

a axis = lavender.
b axis = pinkish lavender.
c axis = violet.

The color effects given above are such as were noted on crystals that had been heated above 160° gradually. If the green crystals be suddenly heated to a high temperature, as, for instance, by putting them on a piece of platinum foil and suddenly heating them in the hot flame of a Bunsen burner, the results are different. The crystals are then considerably cracked, and on brachypinacoidal sections the optical orientation is like that of the green crystals—that is, the *c* axis of the crystal corresponds to a direction of minimum velocity. Moreover the pleochroism is interchanged so that—

a axis = violet.
c axis = lavender.

The changes in the indices of refraction and the birefringence undergone by the green variscite crystals on changing to the lavender phase are also very marked. The mean refractive index drops from 1.560 to about 1.448 and the birefringence from 0.032 to 0.003 or even less. The birefringence does not exceed 0.003 in any section and is much less in most. The approximate values of the indices are as follows:

$$\alpha = 1.447, \beta = 1.448, \gamma = 1.450; \ \gamma - \alpha = 0.003.$$

This decrease in the values of the refractive indices and the birefringence is accompanied by loss of water. It is a fact worth emphasizing that the loss of water, without destroying the optical possibilities of the mineral, decreases both these values.

When the lavender crystals are heated with water on the steam bath (not over 100°) for several days, they gradually lose their lavender color and become a dirty grayish-white. In this condition they are nonpleochroic. A sample treated in this way for about a week was then air-dried for several days, and the loss on ignition (water absorbed) determined. This amount was found to be 2.05 per cent. The ignited crystals again became deep lavender in color. It therefore seemed that it might be possible by appropriate treatment to change the dehydrated lavender crystals back to their original vivid green color. With this in mind, some of the lavender crystals were treated with hot water for several days until they became grayish-white in color, and then sealed in a glass bomb with a little water and heated for several hours at a higher temperature. The glass bomb was first heated for about four hours at 170°, the next day for the same time at 190°, and the third day for the same time at 225°. Unfortunately, it was not possible to heat the tube at these temperatures continuously, as should probably have been done. After three days' heating, as just described, the grayish-white crystals had become a very pale greenish-yellow, but when the crystals were removed from the tube and the loss on ignition determined after air-drying extending over several days, the result was disappointing. A loss of only 1.12 per cent was found, so that the crystals had absorbed less water in the glass bomb treatment than by simply treating with hot water.

The crystals from the glass bomb were very light brown or nearly colorless when viewed under the microscope. Pleochroism was distinct, though very slight. Parallel to the *c* axis, a direction of maximum velocity (unlike the green crystals), light brown; parallel to the *a* axis, a light brown with a decided greenish-yellow tint. The birefringence is about 0.006, the interference colors on the thicker crystals reaching into first order yellow. The areas of "Irregular aggregates" (shown in fig. 3) are more strongly colored and are indefinite in character. They somewhat resemble the kaolinization effects seen in rock slides.

RELATION TO ANALOGOUS MINERALS.

A brief comparison of the optical properties of variscite, as given, with those of the analogous minerals scorodite, strengite, and phosphosiderite, shows some close relationships as well as some marked differences.

The optical properties of variscite given by Lacroix[1] are not entirely in accord with those given in this paper, but this disagreement is due to the fact that Lacroix's material consisted of fibrous material and not of distinct crystals. He gives the axial plane as parallel to *b* {010}, with negative acute bisectrix normal to *a* {100}, whereas the acute positive bisectrix is normal to *c* {001}. The value of 2E is given as about 96° and the mean index as 1.579, which is a little higher than the value 1.560 found on the Utah crystals, but almost identical with the maximum index found on them, namely (γ), 1.578. The birefringence is stated to be a little higher than that of quartz, but the birefringence observed by Lacroix was probably not the maximum, which reached a value of 0.032 in the crystals from Utah.

Comparison of the chief optical properties of the different analogous minerals can be made most conveniently if they are shown in tabular form. The orientation of the variscite is so chosen that the axial phase is *b*(010), but it is possible, as shown in the following pages of this paper, to orient the crystals so that the axial plane is *a* (100), analogous to that of scorodite and strengite.

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[1] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 479.

Comparison of optical relations.

Mineral.	Axial plane.	Optical sign.	Bx_a.	2E.	Mean index.	Birefringence.
				°		
Variscite.............	*b*(010)	+	$\perp$(001)	113	1.560	0.03
Scorodite.............	*a*(100)	+	$\perp$(001)	130	....	.03
Strengite.............	*a*(100)	+	$\perp$(001)	60	1.825	.03
Phosphosiderite......	*b*(010)	+	$\perp$(001)	126	1.73	....

In adopting the orientation for variscite as given in this paper, with the optic axial plane parallel to *b*(010), an interesting condition obtains for the isomorphous mixtures of variscite ($AlPO_4.2H_2O$) and strengite ($FePO_4.2H_2O$), for in the latter mineral the optic axial plane is parallel to *a*(100). Such an isomorphous mixture is represented by the mineral barrandite, of which two analyses are on record and in both of which the iron phosphate predominates, so that barrandite, instead of being a distinct mineral species, is in reality only an aluminous strengite.[1] In strengite the axial plane is *a*(100) and 2E equals 60°, whereas in variscite the axial plane is *b* (010) and 2E is nearly twice as large. The isomorphous admixture of a small amount of variscite in strengite would therefore tend to decrease the axial angle of strengite, and with a certain amount of variscite, the axial angle would become zero. A still greater amount of variscite in the mixture will give an increasing axial angle, but with the axial plane now parallel to *b*(010) as in pure variscite. Since the axial angle of strengite is much smaller than that of variscite, an isomorphous mixture with an axial angle of about zero should contain more strengite than variscite.[2] Both analyses of barrandite show an excess of the strengite molecule, the ratio in the first being 4:3 and in the second 5:2. In the analysis giving the last ratio, it is therefore highly significant to note that Lacroix in describing[3] barrandite states that the optic axes are very close, so that the value of 2E is very small. In the analysis of barrandite given by Lacroix the ratio of Fe_2O_3 to Al_2O_3 is about as 5:2. An approximate calculation of the value of the axial angle of such an isomorphous mixture shows that it should be very small, approximately 10°.

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[1] Compare p. 38.

[2] It is interesting to note that should an isomorphous mixture of variscite and strengite be found (without definite crystals) in such proportions that the axial angle is zero, the discoverer would be very likely to consider the find as a distinct new species, as it would be strictly uniaxial, whereas both variscite and strengite are biaxial.

[3] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 486.

On the other hand, it must be stated that the density and mean refractive index of barrandite, as given by Lacroix, are not consistent with the values calculated from those of variscite and strengite, as the following table shows:

Comparison of values for barrandite.

	Density.	Mean refractive index.
Variscite	2.54	1.560
Strengite	2.87	1.825
Barrandite [a] found	2.59	1.575
Barrandite [a] calculated	2.78	1.749

[a] Barrandite consists of 5 parts strengite and 2 parts variscite.

The wide discrepancies in the found and calculated values of the density and refractive index, respectively, are not in accord with the idea of the isomorphous character of barrandite as developed for the optical properties.

CRYSTALLOGRAPHY.

INTRODUCTION.

The flat crystals are orthorhombic in their symmetry and simple in their combination. The large face is taken as the brachypinacoid, and the chief forms noted, as shown in figure 4, are: *b*(010), *m*(110), and *e*(012). In addition to these forms the macropinacoid *a*(100) is sometimes present as a narrow face. Occasionally the crystals are much longer and the prism faces more developed in comparison with the brachypinacoid. The common habit of the crystals is shown in figure 4. A better idea of the shape of the crystals can be had from figure 3, on page 53, which shows a variscite crystal so drawn as to bring the brachypinacoid *b*(010) in front. The rectangular tabular shape of the crystals, due to the large development of the brachypinacoid, is well illustrated in the same figure.

Several other forms are present on these crystals, but they could not be determined. On crushing some of the coarsely crystallized aggregate and examining it under the microscope one occasionally sees an acutely-terminated crystal which has the corners replaced by small faces, probably those of the unit pyramid.

In orienting the crystals of variscite three positions are available, depending on the pinacoid to which the broad face is referred. This broad face is generally slightly striated vertically. In conformity with the analogous mineral scorodite, the striations are taken as parallel to the *c* axis. Striated crystals of scorodite have been described by several authors. Kokscharow[1] states that the form {010} is strongly striated vertically. Zimanyi[2] describes scorodite crystals on which the prism *d* {120} is vertically striated and Lacroix[3] mentions vertical striations on {120} and the two pinacoids {100} and {010}.

The crystals of variscite have been so oriented that the broad face is *b* {010}, as already described and illustrated in figure 3. Lacroix[4] mentions scorodite crystals slightly flattened parallel either to *a* {100} or to *b* {010}. He also states that a rare phase of strengite is formed by plates flattened parallel to *a* {100}.

The possibilities of the three available orientations will be discussed after the measurements of the variscite crystals are given.

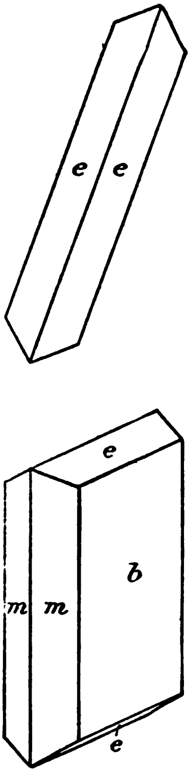

FIGURE 4.—Variscite crystal, *b*(010), *m*(110), *e*(012).

CALCULATION OF ELEMENTS.

Variscite being orthorhombic, only two angular values are necessary for a determination of the crystallographic elements.

The fundamental values of variscite are:

$$b \wedge m = (010) : (110) = 48° \ 10'$$
$$b \wedge e = (010) : (012) = 61° \ 17'$$

From these values the axial ratio is found to be:

$$a : b : c = 0.8952 : 1 : 1.0957.$$

The measurements from which the fundamental values for variscite were obtained are as follows: In the measurements of the angle (010) : (110) it is possible to obtain eight values on each crystal, namely $(010 : 110)$, $(010 : \bar{1}10)$, $(0\bar{1}0 : 1\bar{1}0)$, $(0\bar{1}0 : \bar{1}\bar{1}0)$, $\frac{1}{2}(110 : \bar{1}10)$, $\frac{1}{2}(1\bar{1}0 : \bar{1}\bar{1}0)$, $90° - \frac{1}{2}(110 : 1\bar{1}0)$, $90° - \frac{1}{2}(\bar{1}10 : \bar{1}\bar{1}0)$. In the following table, of these possible eight values, only those are given where the reflections from the faces were fairly good and distinct. The numbers at the heads of the columns refer to individual crystals, and the averages of the various measurements are given below.

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[1] Kokscharow, N., Mineralogie Russlands, vol. 6, 1870, p. 309.

[2] Zimanyi, K., Beiträge zur Mineralogie der Komitate Gömör und Abanj-Torna: Föld. Közl., vol 35, 1905, p. 545.

[3] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 472.

[4] Idem, p. 474.

Measurements of angle $b\wedge m$=(010) : (110).

1		2		4		5		6		7	
°	′	°	′	°	′	°	′	°	′	°	′
48	28	48	26	48	19	48	02	48	07	46	59
47	34	48	11	48	44	48	13	48	12	49	07
48	42	48	33	47	56			48	14	48	04
47	21	47	51	48	22			48	19		
47	55	48	18	48	10						
48	08	48	14								
48	01	48	14	48	18	48	08	48	13	48	03

Average of 26 measurements=48° 10′.

For the faces of *e* {012} the number of possible measurements was not so large, because the crystals measured were broken off at the lower end.

Measurements of angle $b\wedge e$=(010) : (012).

	°	′		°	′
Crystal No. 2...	61	21	Crystal No. 6...	61	31
	61	15		61	10
Crystal No. 3...	61	22	Crystal No. 7...	61	26
	61	08		61	10
Crystal No. 4...	61	28	Crystal No. 8...	61	14
Crystal No. 5...	61	19		61	01

Average of 12 measurements=61° 17′.

The only crystallographic study hitherto made of variscite is the work of Chester[1] on the Arkansas mineral. He found some minute crystals with the forms *b* {010}, *a* {100}, *m* {110}, and *c* {001}. Of these, *b*, *m*, and *c* were well developed. The angle $m\wedge m'''$ (110 : $1\bar{1}0$) is given as 65° 54′, but it has not been possible to correlate this angle with any simple form for the variscite-scorodite group.

The following table gives the coordinate angles for the forms of variscite. The table is adapted for measuring the crystals by the two-circle method, but, of course, it also gives the necessary interfacial angles.

Forms and coordinate angles for variscite.

[a=0.8952, c=1.0957, p_0=1.2240, q_0=1.0957.]

No.	Letter.	Symbol.		φ		ρ	
		Gdt.	Miller.				
				°	′	°	′
1...........................	*b*	0∞	010	0	00	90	00
2...........................	*a*	$\infty 0$	100	90	00	90	00
3...........................	*m*	∞	110	48	10	90	00
4...........................	*e*	$0\frac{1}{2}$	012	0	00	28	43

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[1] Chester, A. H., Note on the crystallization of variscite: Am. Jour. Sci., 3d ser., vol. 15, 1878, p. 207.

The three possible orientations for the variscite crystals will now be given and their relation to the orientation of the analogous minerals scorodite, strengite, and phosphosiderite studied.

FIRST ORIENTATION.

The first orientation is the one chosen for the mineral, as it best shows the relation of variscite to the other minerals and at the same time yields the simplest indices for the crystal forms of variscite. In the comparisons two orientations are given for phosphosiderite, both of which are different from the accepted position of that mineral. The first one, given as phosphosiderite (1) in the following tables, is the one suggested by Bruhns and Busz;[1] and the second one, phosphosiderite (2) is obtained by interchanging the *a* and *c* axes in the generally adopted position and then doubling the new *a* axis.

The close relation between the angles of variscite and the other minerals of analogous composition is shown in the table below:

Comparison of angles (first orientation).

Angle.	Variscite.	Scorodite.	Strengite.	Phosphosiderite.	
				1	2
	° ′	° ′	° ′	° ′	° ′
$b \wedge m$=(010) : (110)	48 10	49 07	49 08	50 33	48 45
$b \wedge e$=(010) : (012)	61 17	64 30	63 50	64 52	61 57

A comparison of the axial ratio also shows clearly the similarity in values and the very close agreement of variscite with phosphosiderite (2). A greater difference is shown by comparison with the values of the other minerals.

Comparison of axial ratios (first orientation).

Mineral.	*a* axis.	*c* axis.
Scorodite	0.8658	0.9541
Strengite	.8652	.9827
Variscite	.8952	1.0957
Phosphosiderite (1)	.8229	.9381
Phosphosiderite (2)	.8772	1.0660

It is worthy of special notice that the agreement of values is much closer for variscite and phosphosiderite (2) than it is for either variscite and scorodite or strengite. This fact led to the suggestion that perhaps the mineral here described was not variscite but a new mineral bearing the same relation to true variscite that phosphosiderite is supposed to bear to strengite. The analysis, however, shows that the crystallized variscite from Utah agrees well with the formula $Al_2O_3.P_2O_5.4H_2O$. A careful study of the relations of phosphosiderite to strengite, considered with the close crystallographic values of phosphosiderite and variscite, leads to the conclusion that phosphosiderite and strengite are identical, notwithstanding the apparent differences in their optical properties.

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[1] Zeitschr. Kryst. Min., vol. 17, 1890, p. 555. Also given in Dana's System of mineralogy, 6th ed., 1892. p. 823.

SECOND ORIENTATION.

In the second possible orientation the large face is made the macropinacoid *a* {100)} As the optical axial plane of variscite is parallel to this pinacoid, such an orientation would bring variscite into optical conformity with scorodite and strengite. It then becomes necessary, however, in order to retain the crystallographic analogy, to give to the prism *m* the symbol {340}. The dome *e* then becomes {102}, and the close angular agreement of the minerals in this position can be seen by the following table:

Comparison of angles (second orientation).

Angle.	Variscite.		Scorodite.		Strengite.		Phosphosiderite.			
							(1)		(2)	
	°	′	°	′	°	′	°	′	°	′
$b\wedge m$=(100) : (340)............	48	10	49	11	49	05	47	39	49	28
$b\wedge e$=(100) : (102)............	61	17	61	02	60	24	60	19	58	43

On the basis of the above angular values, the following comparison of the axial ratios is made:

Comparison of axial ratios (second orientation).

Mineral.	*a* axis.	*c* axis.
Variscite..	0.8379	0.9181
Scorodite..	.8658	.9541
Strengite..	.8652	.9827
Phosphosiderite (1)..	.8229	.9381
Phosphosiderite (2)..	.8772	1.0660

The agreement in values is much closer than for the first orientation, but the prism form loses its simple indices. It must be said, however, that this orientation has much to commend it and may, perhaps, be chosen in the future as the best one for the mineral, especially when the properties of strengite and barrandite are better defined than they are at present.

THIRD ORIENTATION.

A third orientation is made still possible by considering the large face as the basal pinacoid. Though the angular values derived from this orientation show a close agreement, such a habit is entirely at variance with all the other minerals of this group and the choice of orientation must be left to the first or second one.

By making the large face the basal pinacoid and taking *m* as {101} and *e* as {021}, the following comparison is obtained.

Comparison of angles (third orientation).

Angle.	Variscite.	Scorodite.	Strengite.	Phosphosiderite.	
				(1)	(2)
	° ′	° ′	° ′	° ′	° ′
$b \wedge m$=(001) : (101)	48 10	47 47	48 38	48 45	50 33
$b \wedge e$=(001) : (021)	61 17	62 20	63 02	61 57	64 52

From these values the following axial ratios are obtained:

Comparison of axial ratios (third orientation).

Mineral.	*a* axis.	*c* axis.
Variscite	0.8170	0.9126
Scorodite	.8658	.9541
Strengite	.8652	.9827
Phosphosiderite (1)	.8229	.9381
Phosphosiderite (2)	.8772	1.0660

TWIN CRYSTAL.

A twin crystal was observed under the microscope among the crushed aggregate. The twinning plane is {102}, as the inclination of the twinned part of the complex to the untwinned part was measured as 31° and the angle (001): (102) is calculated as 31° 28′. Similar twins were noted on phosphosiderite, again showing the striking crystallographic closeness of variscite with phosphosiderite, and emphasizing the probable identity of phosphosiderite with strengite.

RELATION TO ANALOGOUS MINERALS.

The angular values for the minerals of this group are so close in three different directions that great care must be exercised in choosing the correct position. This should always be verified optically, if possible, for on poor crystals it would be difficult to distinguish with certainty some of the angles. This similarity in angular values can be well shown by the following table:

Comparison of angles showing similarity.

Angle.	Variscite.	Scorodite.	Strengite.	Phosphosiderite.	
	° ′	° ′	° ′	° ′	° ′
(100):(340)	50 03	49 11	49 05	47 39	49 28
(010):(110)	48 10	49 07	49 08	50 33	48 45
(001):(101)	50 45	47 47	48 38	48 45	50 33
(010):(012)	61 17	64 30	63 50	64 52	61 57
(001):(021)	65 28	62 20	63 02	61 57	64 52
(100):(102)	58 32	61 02	60 24	60 19	58 43

It is possible that the mineral vilateite,[1] the violet crystals of Des Cloizeaux's hureaulite, may belong to this group. The crystals are described as monoclinic, but the angular differences from orthorhombic symmetry are slight, and Lacroix states that optically the mineral behaves somewhat like an orthorhombic substance. The similarity in axial ratios to scorodite and the other minerals of the group can be seen in the following table. For vilateite, half the *a* axis, as given by Lacroix, has been taken.

Comparison of axial ratios.

	a axis.	*c* axis.	β
			° ′
Vilateite	0.8479	0.8886	89 27
Variscite [a]	.8379	.9181	90 00
Scorodite	.8678	.9583	90 00
Strengite	.8652	.9827	90 00
Phosphosiderite (1)	.8229	.9381	90 00

[a] Second orientation.

CHEMICAL COMPOSITION.

GENERAL PROPERTIES.

The mineral is infusible before the blowpipe, but, as has been stated, changes its color in a striking way, the emerald green becoming a deep lavender and the crystals taking on a much more brilliant luster. Quantitative analyses show that all the water of the mineral is given off while the change of color is taking place, so that the lavender variscite is anhydrous. Chester [2] mentions a similar change in color for the variscite from Arkansas, but his investigations seem to have been generally overlooked. In describing the properties of the crystallized variscite Chester says: "The colors observed are deep emerald-green. * * * Before the blowpipe it becomes opaque, friable, and of a deep purple when hot, lighter purple when cold. In the glass tube yields much water and changes in color as above." The density of the green mineral was found to be 2.54.

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[1] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 477.

[2] Chester, A. H., On the identity of the so-called peganite of Arkansas with the variscite of Breithaupt and callainite of Damour: Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 295.

The powdered mineral is insoluble in boiling hydrochloric acid, but readily dissolves in acids after dehydration and change in color. The striking color changes observed in the mineral led me to look especially for such rarer elements as had a strong chromatic effect. This search showed that chromium and vanadium were present in small amount and that a trace of iron occurred.

CHEMICAL ANALYSIS.

The results of the quantitative analysis and the ratios deduced therefrom are here given:

Analysis and ratios of crystallized variscite from Lucin, Utah.

	Analysis.	Ratio.	
H_2O	22.68	1.260	4.00
P_2O_5	44.73	.315	1.00
V_2O_3	.32	.002	1.02
Cr_2O_3	.18	.001	
Fe_2O_3	.06	....	
Al_2O_3	32.40	.318	
Ni, Co, Cu	None.	....	
Mn, As			
Ca, Mg			
	100.37		

The ratios agree very well with the formula $Al_2O_3.P_2O_5.4H_2O$, thus comparing with strengite ($Fe_2O_3.P_2O_5.4H_2O$) and not with phosphosiderite ($Fe_2O_3.P_2O_5.3\frac{1}{2}H_2O$), even though the crystals of variscite are much closer in angular values to those of phosphosiderite than to those of strengite.

The results obtained as to loss of water at different temperatures are as follows:

Loss of water on heating.

Temperature.	Color of powdered sample.	Loss of water.
°*C.*		*Per cent.*
....	Pale green	....
110 (first day)	....do	5.09
115 (second day)	Light gray[a]	9.67
110 (third day)	Pale lavender	12.48
140	Lavender	19.81
160	Deep lavender	22.50

[a] The color here called light gray is very difficult to define. The mineral powder had lost its original green color but did not show any decided lavender shade. Perhaps the combination of some lavender and some green gave the resultant effect here called gray.

The vanadium and chromium were determined on a 4-gram portion of the mineral, the method used being that described by Hillebrand.[1] After the chromium had been determined colorimetrically, the correction necessary to apply to the vanadium determination was found by titrating a hot sulphuric acid solution of sodium chromate containing the same amount of Cr_2O_3 as was present in the sample of variscite analyzed. Qualitative tests with ferricyanide showed that there was no ferrous iron in the solution of the mineral which had been heated to 170°. It was, therefore, possible to determine the state of oxidation of the vanadium. For this purpose a gram of the mineral was heated to 160°, which process completely dehydrated it and changed its green color to an intense lavender. The powdered mineral was then dissolved in sulphuric acid and titrated with permanganate. The amount consumed was equivalent to 0.45 per cent V_2O_3, or, corrected for the chromium present, 0.41 per cent V_2O_3. This is higher than the value obtained on the 4-gram sample (0.32 per cent), but the lower result is regarded as the more accurate. It may be here stated that a cold solution of bichromate in sulphuric acid will consume a small but appreciable amount of permanganate, which has to be determined and allowed for in such instances as the present one. The ferric iron was determined colorimetrically, using potassium sulphocyanide.

An adequate explanation of the remarkable color change and of the accompanying changes in physical and optical properties has not been found.

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[1] Hillebrand, W. F., The analysis of silicate and carbonate rocks: Bull. U. S. Geol. Survey No. 422, 1910.

HINSDALITE FROM COLORADO.

INTRODUCTION.

In the description of the new mineral hinsdalite[1] it was stated that it was collected by Mr. E. S. Larsen in the summer of 1910 while he was engaged in the areal mapping of the geology of the San Cristobal quadrangle, Colorado. The mineral was found in considerable quantity at an elevation of about 9,950 feet on one of the dumps of the Golden Fleece mine, which is about 3 miles south of Lake City, Hinsdale County, Colo. The chemical analysis showed hinsdalite to be a hydrous sulphate and phosphate of lead and aluminum with a little strontium replacing the lead. It is therefore the lead analogue of svanbergite, or the aluminum analogue of corkite.

OCCURRENCE.

Mr. Larsen states that the country rock of the mineral occurrence belongs to the Picayune member of the Silverton volcanic series and consists of tuffs, lava flows, and intrusive bodies of rhyolite, latite, and andesite. The tunnel of the mine was not accessible, but from the material on the dump the new mineral appears to occur as an original component of a vein whose chief constituents, in the order of their abundance are quartz, hinsdalite, barite, pyrite, galenite, tetrahedrite, and rhodochrosite. The vein material contains bands of almost pure, coarsely granular hinsdalite, an inch or more across. These bands are bordered by a finely crystalline aggregate of quartz and hinsdalite in which are embedded well-formed crystals, many of them a centimeter across, of the new mineral. Beyond the fine aggregate is nearly pure granular quartz or quartz and barite. The galenite and tetrahedrite, and to some extent the pyrite, are concentrated in the quartz-hinsdalite aggregate.

DESCRIPTION OF MINERAL.

The following description of the mineral is by Mr. Larsen:[1]

> The granular hinsdalite is rather coarsely crystalline and the mineral shows a strong tendency to develop crystal faces. Some of the larger embedded crystals are rhombohedrons resembling cubes, with a perfect cleavage (basal) truncating one corner.

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[1] Larsen, E. S., and Schaller, W. T., Hinsdalite, a new mineral: Am. Jour. Sci., 4th ser., vol. 32, 1911, p. 251.

The crystal faces are always dull and rough, so that accurate measurements were impossible. Several crystals, however, could be measured with a contact goniometer and gave for the angle $r \wedge r'$ the values: 91.0°, 91.3°, 91.2°, 91.7°, average 91.3° or 91° 18′. The value of the c axis computed from this average angle is 1.2677. Measurements of the angle between the cleavage and the adjacent rhombohedron varied from 56° to 59° with an average of 57° 18′. The calculated value for the angle $c \wedge r$ is 55° 40′.

The faces commonly developed on the larger crystals are the unit rhombohedron $r\{10\bar{1}1\}$ and the base c $\{0001\}$. The smaller crystals are tabular parallel to the base and have both the positive and negative rhombohedrons. The basal sections are hexagonal, while the prismatic sections are lath-shaped with pointed ends. The optical properties show, however, that the mineral is only pseudorhombohedral.

The perfect basal cleavage gives wavy and striated surfaces and the striations are in some cases developed in three directions, forming hexagonal markings. The hardness of hinsdalite is about 4.5 and the density is 3.65. The streak is colorless. The luster is vitreous to greasy. The crystals are nearly colorless, with a greenish cast, but much of the mineral is dark gray from minute inclusions.

A microscopic study of thin sections revealed the fact that the larger crystals, at least, are strongly zoned. This zonal structure is easily seen in ordinary light or even in the hand specimens. Some of the zones are much more subject to alteration than others. Between crossed nicols the different zones show slightly different interference colors.

On account of the zonal growth it is not possible to obtain accurate and consistent optical data. Cleavage pieces of the mineral are not isotropic but are nearly normal to a positive, acute, bisectrix. The values of 2E vary from nearly 0° to 40°. Dispersion of the optic axes were not perceptible. In many cases the core of the larger crystals is nearly uniaxial and the most common value of 2E for the outer zones is 32°. The variation in the value of 2E is probably largely due to the zonal growths, though in some cases it is clearly due to overlapping of twin lamellæ. Basal sections of some of the crystals are divided into six radial segments and the plane of the optic axes for each segment is normal to the hexagonal prism edge and to the striations.

Accurate measurements of the angle between the segments was not feasible, though it approximates closely to 60°. Similar optical anomalies have been described for hamlinite [1] and for jarosite,[2] both members of the same series of minerals to which hinsdalite belongs.[3]

The indices of refraction for hinsdalite were determined by the oil-immersion method. The values of α and β are nearly the same and vary from 1.66 to 1.68, with an average value of 1.67; the value of Υ varies from 1.678 to 1.700. The birefringence was measured by comparing the interference color of sections parallel to the plane of the optic axes with that of the same section of quartz. For the greater part of the hinsdalite crystal, the value 0.019 was obtained. Some of the narrow zones gave a value as low as 0.016. Therefore the indices of refraction for hinsdalite may be taken as: α=1.670, Υ=1.671, γ=1.689.

CHEMICAL COMPOSITION.

The mineral is infusible, becomes blue when heated with cobalt nitrate, and gives a lead reaction when fused with sodium carbonate on charcoal. A little water is given off when it is heated in a closed tube. It is practically insoluble in acids.

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[1] Bowman, H. L., On hamlinite from the Binnenthal, Switzerland: Mineralog. Mag., vol. 14, 1907, p. 389.

[2] Slavik, Franz, Mineralogische Notizen: Zeitschr. Kryst. Min., vol. 39, 1904, p. 297.

[3] See the following paper in this volume.

After the qualitative analysis had shown what the essential components of the mineral were, a preliminary quantitative analysis was made, the results of which, though approximately correct, are not here given. With a knowledge of the composition and the experience gained in making the preliminary analyses, the chemical composition of hinsdalite was determined on carefully selected pure material. The results obtained, together with the ratios deduced therefrom, are shown below:

Analysis and ratios of hinsdalite.

	Per cent.	Ratio.	
PbO	31.75	0.142 } .172	1.93 or 2
SrO	3.11	.030 }	
CaO	Trace.		
Al_2O_3	26.47	.260	2.92 or 3
SO_3	14.13	.177	1.99 or 2
P_2O_5	14.50	.102	1.14 or 1
H_2O	10.25	.570	6.40 or 6
	100.21		

The ratios agree well with the formula $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$, except that the P_2O_5 and H_2O are a little high. A comparison of the analysis with the calculated percentages is shown below. The sample analyzed consists of 82.56 per cent of $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$ and 17.44 per cent of $2SrO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$ (svanbergite).

Under 1 is given, in the table below, the analysis of the Colorado mineral; under 2 the calculated composition of $2PbO.3Al_2O_3.2SO_3.P_2O_5.6H_2O$; under 3 the composition calculated for a mixture of 82.56 per cent of the pure lead compound and 17.44 per cent of the pure strontium compound (svanbergite), and under 4, for comparison, the calculated composition of pure svanbergite.

Comparison of analysis with calculated composition.

	1	2	3	4
PbO	31.75	38.37	31.68	....
SrO	3.11	....	3.91	22.43
Al_2O_3	26.47	26.36	27.55	33.19
SO_3	14.13	13.77	14.39	17.32
P_2O_5	14.50	12.21	12.76	15.37
H_2O	10.25	9.29	9.71	11.69
	100.21	100.00	100.00	100.00

The Colorado mineral, or at least that sample of it which was analyzed, represents a strontium hinsdalite just as the only good analysis of svanbergite really represents a lead svanbergite.

The water of the mineral is all water of constitution—that is, it is driven off only at a high temperature. Practically no water was expelled up to 390°. The following table shows the results obtained:

Loss of water.

Temperature.	Total loss in weight.
°C.	*Per cent.*
110	0.02
170	.02
250	.08
390	.08
590	9.24

The crucible was heated in an air oven up to 250°, above which temperature an electric furnace was used. The results show that the water is lost between 400° and 600°, approximately.

In its relation to other members of the group, hinsdalite is best considered as the lead type of svanbergite. It may just as well be considered an aluminous corkite, the formula for corkite[1] being $2PbO.3Fe_2O_3.2SO_3.P_2O_5.6H_2O$. The systematic place of hinsdalite is thus well fixed. It adds another well-defined mineral to a group which already includes a considerable number of minerals.[2] The relations of these minerals are shown by the following tabulation:

Svanbergite....	$2SrO. 3Al_2O_3. 2SO_3. P_2O_5. 6H_2O.$	Rhomb. c=1.2063.
Hinsdalite......	$2PbO. 3Al_2O_3. 2SO_3. P_2O_5. 6H_2O.$	Rhomb. c=1.2677.
Corkite.........	$2PbO. 3Fe_2O_3. 2SO_3. P_2O_5. 6H_2O.$	Rhomb. c=1.1842.
Beudantite.....	$2PbO. 3Fe_2O3. 2SO_3. As_2O_5. 6H_2O.$	Rhomb. c=1.1842.

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[1] Cf. Lacroix, A., Minéralogie de la France, vol. 4, 1911, p. 596.

[2] See following paper in this volume.

THE ALUNITE-BEUDANTITE GROUP.

INTRODUCTION.

The analysis of the mineral hinsdalite, described in the preceding paper, led me to review carefully the various minerals forming the alunite-beudantite group. This review has brought out several points in regard to the relationships of some of these minerals about which it is very desirable to obtain more definite and accurate information. Some of the suggestions offered in this paper must remain unsettled until such new work can be performed. Prior[1] has compared the various minerals belonging to this group and has clearly shown their similarity in composition and in crystal form. Before this comparison is repeated here, a short discussion of the members or possible members of this group will be given.

PROBABLE IDENTITY OF HAMLINITE WITH GOYAZITE.

Goyazite was described by Damour[2] in 1884 as a hydrous phosphate of alumina and lime, the rather improbable formula $3CaO.5Al_2O_3.P_2O_5.9H_2O$ being given for it. Hussak[3] has recently tested the original specimens of Damour, and has found strontium to be present in greater amount than lime, so that goyazite is, in reality, a hydrous phosphate of alumina and strontia. Hartley, in analyzing plumbogummite,[4] has suggested that the accuracy of Damour's separation of P_2O_5 from Al_2O_3 is open to serious question because of the method used. If a similar inaccuracy is true for his analysis of goyazite, an interesting conclusion becomes at once evident—namely that the mineral described and analyzed by Penfield and named by him hamlinite is identical with goyazite. The probable identity of goyazite and hamlinite can be best shown by a comparison of their properties.

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[1] Prior, G. T., Note on a connection between the molecular volume and chemical composition of some crystallographically similar minerals: Mineralog. Mag., vol. 13, 1903, p. 217.

[2] Bull. Soc. min. franç., vol. 7, 1884, p. 204.

[3] Hussak, E., Über die sogenannten "Phosphat-Favas" der diamentführenden Sande Brasiliens: Min. pet. Mitt., vol. 25, 1906, p. 335.

[4] Hartley, E. G. J., On the constitution of the natural arsenates and phosphates: Mineralog. Mag., vol. 12, 1900, pp. 223, 225.

Comparison of goyazite and hamlinit

Goyazite.	**Hamlinite.**
Yellowish, white.	Colorless, yellowish.
Semitransparent.	Transparent.
Uniaxial, positive.	Uniaxial, positive.
Tetragonal or hexagonal.	Hexagonal (rhombohedral).
Cleavage, basal.	Cleavage, basal.
H=5.	H=4.5.
G=3.26.	G=3.228, 3.159-3.283.
Per cent $Al_2O_3+P_2O_5=65.53$.	Per cent $Al_2O_3+P_2O_5=62.87$.
Fuses with difficulty.	Fuses about 4.

The hamlinite from Maine contains a little barium and fluorine, but their amount, in comparison to that of strontium and water (hydroxyl), respectively, is small. Moreover, the absence of barium and fluorine in goyazite has not been established.

UTAHITE AND RELATED MINERALS.

On the basis of our present knowledge, utahite, cyprusite, raimondite, pastreite, carphosiderite, and apatelite form a group of minerals which are very closely related. They are all hydrous sulphates of ferric iron with very similar quantitative composition, and all occur in hexagonal or rhombohedral scales. The only one of these minerals which has been found in measurable crystals is utahite, for which two values for the *c* axis have been given, namely, 1.1389 and 1.0576. If it is considered that the material analyzed was many times of doubtful purity and that perhaps the analytical methods used were not always of the best, the differences in their analytical figures become of minor importance, and it seems almost justifiable to regard them all as identical. They may be placed chemically in three divisions, according to their formulas, as follows:

I.	Utahite	$3Fe_2O_3.3SO_3.6H_2O$.
II.	Carphosiderite	$3Fe_2O_3.4SO_3.10H_2O$.
	Apatelite	$3(Fe,Al)_2O_3.3SO_3.9H_2O$.
III.	Raimondite	$2Fe_2O_3.3SO_3.7H_2O$.
	Pastreite	$2Fe_2O_3.3SO_3.7H_2O$.
	Cyprusite	$4(Fe,Al)_2O_3.5SO_3.7H_2O$.

These different formulas are all very closely related and when it is considered that, so far as the published descriptions go, the crystalline form of all these minerals is the same, it seems reasonable to regard them as identical. The above formulas are all close to

$$3Fe_2O_3.4SO_3.7H_2O,$$

though to none of the minerals has this formula been ascribed. This formula corresponds to that of a jarosite in which the K_2O is replaced by H_2O, as will be evident from the following comparison:

Jarosite	$K_2O.3Fe_2O_3.4SO_3.6H_2O$.
New formula	$H_2O.3Fe_2O_3.4SO_3.6H_2O$.

The formulas of carphosiderite and apatelite[1] may be expressed in similar form, for these minerals differ from the type only in containing a slightly greater amount of water:

$$\text{Carphosiderite} = H_2O.3Fe_2O_3.4SO_3.6H_2O + 3H_2O.$$

I would therefore propose that, unless careful work proves to the contrary, carphosiderite, apatelite, raimondite, pastreite, cyprusite, and utahite be regarded as the same mineral with the formula $H_2O.3Fe_2O_3.4SO_3.6H_2O$, and that to this mineral the name carphosiderite be applied by right of priority.

The compilation of analyses of these minerals, given in the accompanying table, shows their close chemical relationship and their general agreement with the formula $H_2O.3Fe_2O_3.4SO_3.6H_2O$.

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[1] Apatelite is only an aluminous carphosiderite.

Analyses of carphosiderite.

	Calculated.	Utahite.		Cyprusite.	Pastreite.		Raimondite.	Carphosiderite.		Apatelite.
		1	2 [a]		1	2		1	2	
H_2O	13.5	9.35	[12.41]	11.06	16.04	13.95	17.40	18.30	18.48	19.2
SO_3	34.7	28.45	26.83	35.34	30.47	30.55	36.08	31.82	30.18	29.7
Fe_2O_3	51.8	58.82	58.51	49.68	46.50	52.80	46.52	49.88	48.52	40.0
Al_2O_3				3.89						11.0
X		[b] 3.19	[c] 2.19		[d] 6.40	[e] 2.68			[f] 2.72	
	100.0	99.81	100.00	99.97	99.41	99.98	100.00	100.00	99.90	99.9
Density				1.7-1.8 !			3.19-3.22	2.49	2.73	3.2

[a] Arzruni and Thaddeeff, Zeitschr. Kryst. Min., vol. 31, p. 244.

[b] As_2O_5.

[c] Insoluble.

[d] SiO_2, 2.40; As_2O_5, 1.86; PbO, 1.25; (Al_2O_3, MnO, CaO), 0.89.

[e] As_2O_5, 2.05; (Al_2O_3, CaO, sand), 0.63.

[f] P_2O_5.

MISCELLANEOUS NOTES.

Though the members of the group are uniaxial rhombohedral, yet optical anomalies indicating biaxiality have been noted for a sulphate (jarosite), a phosphate (hamlinite), and a compound sulphate-phosphate (hinsdalite). Jarosite has been described as showing optical anomaly by Slavík,[1] who found that jarosite from Schlaggenwald showed, in basal section, a division into six parts, each part being biaxial, the trace of the axial plane normal to the prism edge. The negative, biaxial interference figure varied in size in different crystals, up to 32°. Some basal plates were pleochroic and decidedly doubly refracting.

Hamlinite [2] from Switzerland, at first thought to be a new species and called bowmanite,[3] shows optical anomalies. The larger crystals show a division into six sections, each showing a positive, biaxial figure, 2E varying from 0° to 50°. Hinsdalite likewise shows a pseudohexagonal character,[4] the crystals being built up of six sectors, each normal to an acute bisectrix, 2E varying from 0° to 40°. These optical anomalies are very suggestive of dimorphism in the series.

The isomorphous relation of sulphate and phosphate is still further confirmed by the presence of 2.72 per cent P_2O_5 in an analysis of carphosiderite from France and also by the presence of nearly 1 per cent P_2O_5 in a sample of alunite from Utah, tested by the writer.

The formulas of beudantite and corkite have been taken as suggested by Lacroix [5]; the arsenate has been called beudantite and the phosphate corkite. The composition of miriquidite, munkforssite, and munkrudite are too little known to include them definitely in this group, although their qualitative composition suggests that they belong to it.

Pharmacosiderite has been shown [6] to contain considerable potash, and Hartley's formula, $2FeAsO_4.Fe[O(HK)]_3.5H_2O$, can be written in such a form as to show its analogy to hamlinite, as $2(H,K)_2O.3Fe_2O_3.2As_2O_5.7H_2O + 4H_2O$, in which formula the $4H_2O$ does not really belong to the mineral. Though pharmacosiderite is considered isometric, the form is very similar to the rhombohedral crystals of this group, and it would be highly desirable to test the mineral optically to see if it could be referred to a uniaxial mineral, as it commonly shows weak double refraction.

The composition of plumbogummite still needs careful study, for it is entirely possible that more than one species is included under that name. The analyses of Hartley have established the presence in quantity of CO_2 in some varieties, while the analyses of Brazilian plumbogummite, given by Hussak, are free from any CO_2, although these latter contain more water than is usual. Perhaps the fine grinding of the samples has a very marked effect on the water content of these minerals, as Hartley has suggested for pharmacosiderite.

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[1] Slavík, Franz, Mineralogische Notizen: Zeitschr. Kryst. Min., vol. 39, 1904, p. 297.

[2] The name hamlinite is retained until its identity with or distinction from goyazite is definitely determined.

[3] Bowman, H. L., On hamlinite from Binnenthal, Switzerland: Mineralog. Mag., vol. 14, 1907, p. 389.

[4] See the preceding paper in this volume.

[5] Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 592.

[6] Hartley, E. G. J., On the constitution of the natural arsenates and phosphates: Mineralog. Mag., vol. 12, 1899, p. 152.

The mineral called harttite is an isomorphous mixture of about two parts of hamlinite and one part of a strontium alunite. More accurately the ratio is 1.97 parts to 1 instead of exactly 2 to 1. Its formula may therefore be written $2[2SrO.3Al_2O_3.2P_2O_5.7H_2O]+1[SrO.3Al_2O_3.4SO_3.6H_2O]$, which can be simplified to $5SrO.9Al_2O_3.4P_2O_5.4SO_3.20H_2O$. This is very close to the formula deduced by Hussak, which when quadrupled becomes $4SrO.8Al_2O_3.4P_2O_5.4SO_3.20H_2O$. In fact, the ratios deduced by Hussak from the analysis of harttite are in better agreement with the formula here proposed than with his own.

Ratios of harttite.

	Ratio of analysis.		Required by Hussak's formula.	Required by Schaller's formula (approximately).
SrO	1664	4.57	4.00	5.00
Al_2O_3	3355	9.22	8.00	9.00
P_2O_5	1528	4.20	4.00	4.00
SO_3	1475	4.05	4.00	4.00
H_2O	1733	19.60	20.00	20.00

CLASSIFICATION OF MINERALS OF THE GROUP.

The minerals forming the alunite-beudantite group may be divided into three smaller groups, the sulphates, the phosphates, and the sulphate-phosphates. Taking alunite as the type of the sulphates, hamlinite of the phosphates, and corkite as that of the sulphate-phosphates, we have:

Alunite...... $K_2O. 3Al_2O_3.4SO_3.6H_2O$.
Hamlinite.... $2SrO. 3Al_2O.2P_2O_5.7H_2O$.
Corkite...... $2PbO.3Fe_2O_3.2SO_3.P_2O_5.6H_2O$.

The analogous composition is not clearly seen in the three formulas just given, but it is possible, by rewriting them in a slightly different form, to show very clearly the analogy between them:

Alunite....... $K_2O.3Al_2O_3.6H_2O.2SO_3.2SO_3$.
Hamlinite.... $SrO.3Al_2O_3.6H_2O.2HPO_3.Sr(PO_3)_2$.
Corkite..... $PbO.3Fe_2O_3.6H_2O.2SO_3.Pb(PO_3)_2$.

By assuming the isomorphous replacement of SO_3 by HPO_3, the relationships become very clear. The formula can be, however, better written by regarding $=[SO_4]$ and $=[HPO_4]$ as the isomorphous groups which are replaceable. The formulas for these minerals then become:

Alunite.......$[Al(OH)_2]6.K_2.[SO_4]_2.\ [SO_4]_2.$
Hamlinite ...$[Al(OH)_2]6.Sr.\ [HPO_4]_2.[Sr(PO_4)_2].$
Corkite......$[Fe(OH)_2]6.Pb.[SO_4]_2.\ [Pb(PO_4)_2].$

The general formula is written

$$[R'''(OH)_2]_6.R''.[M]_2.[M]_2,$$

in which

$R''' = Al, Fe'''.$
$R'' = K_2, Na_2, H_2, Pb, Sr, Ba.$
$M = SO_4, HPO_4, HAsO_4, Pb_{\frac{1}{2}}PO_4, Sr_{\frac{1}{2}}PO_4.$

The entire group then consists of the following minerals:

Sulphates.—Type formula $[R'''(OH)_2]_6.R'_2$ *or* $R''.[SO_4]_2.[SO_4]_2.$

Alunite............$[Al(OH)_2]_6.K_2.[SO_4]_2.[SO_4]_2.$
Natroalunite......$[Al(OH)_2]_6.Na_2.[SO_4]_2.[SO_4]_2.$
Jarosite...........$[Fe(OH)_2]_6.K_2.[SO_4]_2.[SO_4]_2.$
Natrojarosite......$[Fe(OH)_2]_6.Na_2.[SO_4]_2.[SO_4]_2.$
Plumbojarosite....$[Fe(OH)_2]_6.Pb.[SO_4]_2.[SO_4]_2.$
Carphosiderite.....$[Fe(OH)_2]_6.H_2.[SO_4]_2.[SO_4]_2.$

Phosphates.—Type formula $[R'''(OH)_2]_6.R''.[R'PO_4]_2.[R''(PO_4)_2].$

Hamlinite........$[Al(OH)_2]_6.Sr.[\ HPO_4]_2.[\ Sr(PO_4)_2].$
Plumbogummite..$[Al(OH)_2]_6.Pb.[\ HPO_4]_2.[Pb(PO_4)_2].$
Gorceixite.........$[Al(OH)_2]_6.Ba.[\ HPO_4]_2.[Ba(PO_4)_2].$
Florencite.........$[Al(OH)_2]_6.Ce_{\frac{2}{3}}.[Ce_{\frac{1}{3}}PO_4]_2.[Ce_{\frac{2}{3}}(PO_4)_2].$

Sulphate-phosphates.—Type formula $[R'''(OH)_2]_6.R''.[SO_4]_2.[R''(PO_4)_2].$

Beudantite........ $[\ Fe(OH)_2]_6.Pb.[SO_4]_2.[Pb(AsO_4)_2].$
Corkite............ $[\ Fe(OH)_2]_6.Pb.[SO_4]_2.[Pb(PO_4)_2].$
Svanbergite....... $[\ Al(OH)_2]_6.Sr.[SO_4]_2.[Sr(PO_4)_2].$
Hinsdalite......... $[\ Al(OH)_2]_6.Pb.[SO_4]_2.[Pb(PO_4)_2].$

$$\text{Harttite..........}\begin{cases}[\ Al(OH)_2]_6.Sr.[SO_4]_2.[SO_4]_2.\\ 2([Al(OH)_2]_6.Sr.[HPO_4]_2.[Sr(PO_4)_2]).\end{cases}$$

SOME MINERALS FROM BEAVER COUNTY, UTAH.

INTRODUCTION.

While making an examination of some of the mines in Beaver County, Utah, in the summers of 1909 and 1910, Mr. B. S. Butler, of the United States Geological Survey, collected several minerals that on examination proved to be of unusual interest. One of these is a species not hitherto known, a second has never before been reported from this continent, and a third, although previously reported from but two localities, was found to be relatively abundant in this district.

BEAVERITE.

From the Horn Silver mine, near the town of Frisco, a mineral was obtained that proved on examination in the laboratories of the United States Geological Survey to be a new species. For this mineral, which is a hydrous sulphate of copper, lead, and ferric iron, the name beaverite was proposed,[1] after the name of the county from which it was first described.

OCCURRENCE AND ASSOCIATION.

As described by Butler, the mineralization in the Horn Silver mine occurs along a fault plane that has thrown Tertiary lavas down against Cambro-Ordovician limestone, the ore deposits being mainly a replacement of the volcanic rocks. The principal primary minerals of the deposit are galena, sphalerite, wurtzite, pyrite, chalcopyrite, a sulphantimonite of lead possibly jamesonite, pyrargyrite, argentite, quartz, barite, and sericite. The mine has been developed to a depth of 1,600 feet. For about 600 feet the primary minerals have been almost entirely altered by descending solutions, and this alteration has taken place in lesser degree to a much greater depth. The characteristic alteration in the deposit is to sulphates, with some secondary carbonates, chlorides, and sulphides. The following secondary minerals have been recognized: Anglesite, cerussite, plumbojarosite, jarosite, beaverite, linarite, bindheimite ?, smithsonite, calamine, goslarite, covellite, chalcocite, brochantite, malachite, azurite, chyrsocolla, chalcanthite, cerargyrite, sulphur, chalcedony, kaolinite, gypsum, alunite, and hydrous oxides of iron and manganese. The beaverite occurs with other secondary minerals in the upper part of the deposit. Only a small portion of the upper levels was accessible at the time of visit and the mineral was not seen in place, but the frequency with which it was met in the old dumps leads to the belief that it must have been rather common in some parts of the deposit.

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[1] Butler, B. S., and Schaller, W. T., Some minerals from Beaver County, Utah: Am. Jour. Sci., 4th ser., vol. 32, 1911, p. 418.

PHYSICAL PROPERTIES.

The mineral is a canary-yellow material of earthy appearance, commonly mixed with other secondary lead and copper minerals, but of less common occurrence in small masses that appear to be composed of a single mineral. Such masses are easily crushed in the fingers. Under the high power of the microscope the material is seen to be crystallized in distinct hexagonal plates, too small for accurate measurement of the crystal angles or for determination of the optical character. The refractive index of the light ray vibrating perpendicular to the plates is higher than 1.74.

Almost every crystal contains a minute inclusion whose character has not been determined. The material analyzed appeared under the microscope to be very pure except for these inclusions, and it is possible that the silica that appears in the analyses is due to them.

CHEMICAL COMPOSITION.

The mineral is soluble in boiling hydrochloric acid, leaving the insoluble matter, chiefly silica, behind. On cooling, lead chloride separates out in considerable amounts. The lead reaction can also be readily obtained with sodium carbonate on charcoal. On adding ammonia in excess to the hydrochloric acid solution, the ferric iron is thrown down as a voluminous brown precipitate and the solution takes the deep blue color indicative of copper. By quantitative determination the presence of a small amount of alumina was established. The insoluble matter consists mostly of silica, only a slight residue remaining after treatment with hydrofluoric acid.

The average of the results of the chemical analyses is shown in the table below. The ratios obtained therefrom are also given.

Analysis and ratios of beaverite.

	Per cent.	Ratio.	
Insoluble	10.05	....	....
CuO	9.70	0.121	0.92 or 1
PbO	29.44	.132	1.00 or 1
Fe_2O_3	17.28	.108 } .144	1.07 or 1
Al_2O_3	3.64	.036	
SO_3	21.32	.266	2.01 or 2
H_2O	9.02	.501	3.80 or 4
	100.45		

The ratios agree well with the formula $CuO.PbO.Fe_2O_3.2SO_3.4H_2O$, in which the copper and lead are assumed to be present in equal molecular amounts and in which a little ferric iron is replaced by alumina. As the ratio of Fe_2O_3 to Al_2O_3 is as 3 : 1, the formula can be written more exactly as $4CuO.4PbO.3Fe_2O_3.Al_2O_3.8SO_3.16H_2O$. A comparison of the analysis reduced to 100 per cent after deducting the insoluble matter, with the values calculated for the formula last given, is shown below.

Comparison of analysis with calculated values.

	Analysis.	Calculated.
CuO	10.74	11.70
PbO	32.50	32.80
Fe_2O_3	19.13	17.61
Al_2O_3	4.03	3.75
SO_3	23.60	23.54
H_2O	10.00	10.60
	100.00	100.00

The water is all constitutional, as none was driven off below 250°. The actual results obtained are as follows:

Loss of weight of beaverite on heating.

Temperature.	Total loss.
°*C.*	*Per cent.*
110	0.04
170	.10
250	.14
390 [a]	3.72
590 [a]	10.45

[a] Heated in an electric furnace.

The loss at 590°, as given, is higher than the true value, as a little of the material was lost by adhering to the thermal couple, which accidentally dropped into the crucible.

No known mineral could be found with which beaverite seems to be related, so that for the present, at least, it must stand as an isolated member of the sulphate group.

WURTZITE.

OCCURRENCE.

The hexagonal zinc sulphide, wurtzite, is, according to Butler, present in considerable abundance in the primary ores of the Horn Silver mine. The principal primary minerals of this deposit have been noted above. The richer zinc ore, in the hand specimen, has the general appearance of light honey-yellow sphalerite, but under the microscope a portion is seen to be rather strongly birefringent, and some of this birefringent material has the outline of pyramidal crystals. Close examination of the mineral revealed pyramidal crystals that could be separated from the surrounding material.

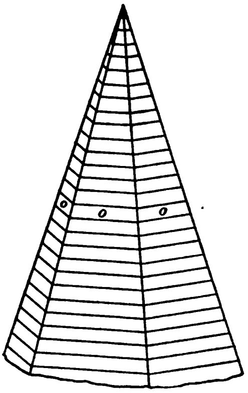

FIGURE 5.—Wurtzite, o {$20\bar{2}1$}.

CRYSTALLOGRAPHY.

Several of these crystals were removed from the matrix and measured. They showed a steep hexagonal pyramid which was strongly striated horizontally. Accurate measurements were not possible, as the striations caused the crystals to become rounded with consequent absence of plane faces. The crystals were measured on the two-circle goniometer and the ρ angle determined for the pyramid faces. This angle corresponds to that between the basal plane (absent on these crystals) and the pyramidal faces. The values obtained are shown below, the pyramid being the form o {$20\bar{2}1$}:

Measurements of o{$20\bar{2}1$} wurtzite.

Crystal No.	1	2	3	4
Average measurement	61°	62°	60°	61°

Calculated value, 62° 06′.

The general habit of these crystals is shown in figure 5, in which the marked horizontal striæ are also shown.

The crystals of wurtzite dissolve readily in hydrochloric acid, giving off hydrogen sulphide. The solution contained abundant zinc, and no other metal was present in appreciable quantity.

Butler noted that the zinc sulphides in this mine have the property of tribo-luminescence, or of giving out light when scratched. This property is so marked that sulphides of zinc can be readily detected in the mine by drawing the point of the pick or mine candlestick across the ore. If zinc sulphides are present the point of the metal is followed by a line of sparks.

PLUMBOJAROSITE.

OCCURRENCE AND PHYSICAL PROPERTIES.

Plumbojarosite has previously been described from two localities, first from Cooks Peak, N. Mex.,[1] and second from American Fork, Utah.[2]

Mr. Butler found this rare mineral in no less than six mines and prospects in Beaver County (the Horn Silver, Hub, Moscow, Red Warrior, and Harrington-Hickory mines, and an unnamed prospect pit), and in some places a considerable quantity could be picked from the ore bins and dumps. It was reported that several tons of the mineral had been thrown on the dump of one mine and later, when found to contain metal values, had been shipped to the smelter.

The following description of its occurrence and physical properties is by Butler:

> The mineral is secondary, resulting from the alteration of ore composed mainly of sulphides of iron, lead, copper, and zinc. The secondary minerals for the most part are the oxides, sulphates, carbonates, and silicates of these metals, and with these are plumbojarosite, frequently jarosite, and other minerals in varying amounts. It is of interest to note that from the Horn Silver mine three members of the jarosite group were determined, namely, jarosite, plumbojarosite, and alunite.
>
> As seen in the hand specimen, the material is dark brown in color and distinctly micaceous in appearance, with a silky luster. Where the crystals are very fine the micaceous character is less pronounced, and the mineral, if not examined with some care, might be mistaken for limonite or some iron-stained material. Although the mineral is frequently in rather large pieces as it comes from the mine, it is readily crushed in the fingers and has an oily look and feel, similar to fine graphite. Under the microscope the crystals are seen to be thin hexagonal plates of a light golden-yellow color. The crystals vary greatly in size but rarely exceed 0.25 mm. in width. Measurement of the crystals has not been made, but they are undoubtedly hexagonal, and, so far as their properties have been determined, they correspond to the material examined by Wright from the American Fork locality. The crystals are uniaxial, optically negative with strong birefringence. It may be noted that the jarosite from the same mines is so similar to the plumbojarosite in physical properties that a distinction can be made only by chemical tests.

CHEMICAL COMPOSITION.

The analysis of the plumbojarosite is shown in the table below, where, for comparison, are also given the two analyses, by Hillebrand, of the mineral from New Mexico and American Fork, Utah. The values calculated from the formula $PbO.3Fe_2O_3.4SO_3.6H_2O$ are also given in the last column for comparison.

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[1] Hillebrand, W. F., and Penfield, S. L., Am. Jour. Sci., 4th ser., vol. 14, 1902, p. 213.

[2] Hillebrand, W. F., and Wright, F. E., Am. Jour. Sci., 4th ser., vol. 30, 1910, p. 191.

Analyses of plumbojarosite.

	Beaver County, Utah.	Cook's Peak, N. Mex.	American Fork, Utah.	Calculated.
Fe_2O_3	42.11	42.37	42.87	42.38
PbO	18.32	19.84	18.46	19.74
K_2O	.13	.17	.15	....
Na_2O		.21	.52	....
SO_3	27.59	27.06	27.67	28.33
H_2O	9.16	9.56	10.14	9.55
CuO	....	.27	.10	....
CaO	....	.05	.06	....
Insoluble	2.64	.51	.40	....
ZnO	.30	....	....	....
	100.25	100.15	100.37	100.00
Density	3.60	3.665	....	....

The three analyses agree closely with each other and with the calculated values.

CORKITE.

OCCURRENCE AND PHYSICAL PROPERTIES.

Mr. Butler states that—

> A light yellowish-green mineral that has the properties of corkite, a hydrous phosphate and sulphate of lead and iron, was collected from the Harrington-Hickory and the Wild Bull mines. So far as is known, these are the only localities on this continent from which the mineral has been reported.
>
> In both of the mines mentioned the original ores were a replacement of limestone near the intrusive rock, and considerable quantities of apatite and contact silicates were formed with the metallic sulphides, mainly pyrite, galena, sphalerite, and chalcopyrite. The corkite is a secondary mineral resulting from the alteration of these ores, the phosphate doubtless being derived from the apatite and the metallic content from the sulphides.
>
> In physical properties the mineral corresponds with that previously described. In the hand specimen it is a light-green, earthy-looking material, which when crushed in the fingers has a gritty feel like fine sand. Under the microscope it is seen to be well crystallized, the larger crystals being 0.15 millimeter in diameter. The crystals are golden yellow and have the general appearance of being a combination of the cube and octohedron. They are rather strongly birefringent, however, and are probably hexagonal rhombohedral. The index of refraction is higher than 1.74.

CHEMICAL COMPOSITION.

Corkite is readily soluble in boiling hydrochloric acid, from which solution lead chloride separates out in quantity on cooling. The solution contains, besides lead, abundant ferric iron and the sulphate and phosphate radicles. Qualitative tests failed to show the presence of any arsenic, and only a mere trace of copper is present. Heated in a closed tube, the mineral darkens and gives off water.

FERRITUNGSTITE FROM WASHINGTON.

A sample of tungstic ocher was collected by Mr. Howland Bancroft, of the United States Geological Survey, from the Germania tungsten mine of the Deer Trail mining district, in the northeastern part of the State of Washington. Mr. Frank L. Hess, also of the Survey, suggested that the tungstic ocher might prove of sufficient interest to warrant careful study. On microscopic examination, the earthy-looking ocher was found to be well crystallized and pure, and chemical tests showed that the ocher was a hydrous ferric tungstate, entirely different from ordinary tungstic ocher, or tungstite, which, as Walker [1] showed, has the formula $WO_3.H_2O$. For the privilege of describing this interesting new mineral I am deeply indebted to the two gentlemen above named.

Examination under the microscope shows that ferritungstite crystallizes in hexagonal plates, evenly developed but very minute. Those lying flat on the base are isotropic under crossed nicols but are too small to exhibit any interference figures. Such crystals as are partially tilted show decided double refraction on their edge. A small quantity of gangue, mostly quartz, is mixed with the mineral, but limonite stains are almost absent, though here and there traces can be seen. Probably less than one per cent of limonite is present in the purest ocher, such as was analyzed.

Ferritungstite results from the oxidation of wolframite and is associated with that mineral in massive quartz. The cleavage, hardness, and density of ferritungstite could not be determined. Its color is pale yellow to brownish yellow when pure. It gives off water in a closed tube and is decomposed by acids, yellow oxide of tungsten separating out.

Only a few tenths of a gram of pure material was available for analysis. Two samples were taken at different times from the same specimen. Qualitative tests showed the absence of MoO_3, SO_3, P_2O_5, and, in general, of substances other than those given in the analyses. The analyses of the two samples are given below.

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[1] Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 305.

Analyses of ferritungstite.

	1	2
WO_3	37.1	35.8
Fe_2O_3	26.6	27.3
H_2O [a]	18.6	20.9
Insoluble	14.7	[16.0]
	97.0	100.0

[a] H_2O determined by loss on ignition.

The ratios deduced from these analyses are shown in the following table:

Ratios of analyses of ferritungstite.

	1	2
WO_3	0.16 or 0.94	0.15 or 0.88
Fe_2O_3	.17 or 1.00	.17 or 1.00
H_2O	1.03 or 6.06	1.16 or 6.82

These ratios are close enough to 1:1:6 to show that the formula for ferritungstite is $Fe_2O_3.WO_3.6H_2O$. Below are shown the two analyses with the insoluble matter deducted and recalculated to 100 per cent, compared with the theoretical values calculated from the formula $Fe_2O_3.WO_3.6H_2O$.

Comparison of analyses with calculated composition.

	Analysis 1.	Analysis 2.	Calculated.
WO_3	45.1	42.6	46.4
Fe_2O_3	32.3	32.5	32.0
H_2O	22.6	24.9	21.6
	100.0	100.0	100.0

The mineral is different from any yet described, and the new name proposed, ferritungstite, shows its chemical relation to ordinary tungstic ocher or tungstite.

NOTES ON MINERALS FROM GABBRO OF WAIMEA CANYON, HAWAII.

INTRODUCTION.

The following brief crystallographic descriptions are based on material furnished by Dr. Whitman Cross of the United States Geographical Survey, to whom I am indebted for his kind permission to publish these results. The crystals were found projecting into the cavities of a coarse gabbro (Dr. Cross's No. 15K) bowlder in the stream bed about one-fourth mile up the east branch of Waimea Canyon, which enters the main canyon about 5 miles above the mouth.

APATITE.

Apatite is present in long slender needles, colorless and transparent except where covered with an opaque grayish coating. The crystals, when terminated, show as prominent forms only $m\{10\bar{1}0\}$ and $x\{10\bar{1}1\}$. The six faces of the unit pyramid are usually triangular in shape and not all of uniform size. Besides the two dominant forms, *m* and *x*, there were noted five other forms, all very poorly developed. The prism $a\{11\bar{2}0\}$ is present as a long line face, and very minute striæ, corresponding to faces of $h\{21\bar{3}0\}$ and $k\{41\bar{5}0\}$, were also noted. The base $c\{0001\}$ and the pyramid $y\{20\bar{2}1\}$ were measured, the faces representing these forms being very minute short line faces. All the faces except some of those of *m* and *x* gave very poor and indistinct reflections.

The following measurements are the averages of the obtained values, on which the identification of the forms are based. The angles for the calculated values are taken from Goldschmidt's Winkeltabellen.

Measured and calculated angles of apatite.

Letter.	Form.	Measured.		Calculated.	
		ϕ	ρ	ϕ	ρ
		° ′	° ′	° ′	° ′
m.......	$10\bar{1}0$	0 00	90 00	0 00	90 00
a.......	$11\bar{2}0$	30 04	90 00	30 00	90 00
h.......	$21\bar{3}0$	18 13	90 00	19 06	90 00
k.......	$41\bar{5}0$	11 38	90 00	10 53	90 00
c.......	0001	....	1 00	....	0 00
x.......	$10\bar{1}1$	0 00	40 00	0 00	40 16
y.......	$20\bar{2}1$	0 00	60 00	0 00	59 27

ORTHOCLASE.

A single square prism of orthoclase was suitable for measurement. Both ends were broken off, so that the only forms identified are *c*{001}, *b*{010}, and *n*{021}. The measurements are as follows: $c \wedge b = 89° 50' - 90° 17'$ (90° 00′ calculated); $b \wedge n = 45° 08'$ (45° 03′ calculated).

TITANIFEROUS AUGITE.

The crystals of augite are small, being about 3 millimeters high (*c* axis), 2½ millimeters wide (*b* axis), and slightly less than 1 millimeter thick (*a* axis). They are black and shining, but on the broken surface show the peculiar violet tinge possessed by titanium-rich augites.

Two crystals were found that could be measured. They both have the same habit, being stout tabular parallel to the orthopinacoid. The crystals are terminated by two large faces of the negative unit pyramid $\{\bar{1}11\}$.

The prism zone is fairly rich in faces, there being measured 11 faces belonging to six forms on the first crystal and 14 faces of five forms on the second crystal. Two of the prisms are new for augite.

The forms observed on these two crystals are as follows, the new forms being starred: *a*{100}, *b*{010}, *m*{110}, *Δ*{150}, **θ*{230}, **ϒ*{530}, *g*{210}, *s*$\{\bar{1}11\}$. The following table gives a comparison of the angles measured and calculated.[1]

Measured and calculated angles of augite.

Letter.	Symbol.	Measured.		Calculated.	
		ϕ	ρ	ϕ	ρ
		° ′	° ′	° ′	° ′
a.......	100	90 00	90 00	90 00	90 00
b.......	010	0 02	90 00	0 00	90 00
m.......	110	43 37	90 00	43 33	90 00
Δ.......	150	11 12	90 00	10 46	90 00
θ	230	32 09	90 00	32 22	90 00
ϒ........	530	58 09	90 00	57 45	90 00
g.......	210	63 05	90 00	62 15	90 00
s........	$\bar{1}11$	25 34	33 36	25 07	33 04

Following is given a brief description of the different forms, arranged in the order of their size.

The orthopinacoid, *a*{100}, is by far the largest form on these crystals, and thereby determines their habit. The faces are striated vertically, though the reflections obtained were fairly good.

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[1] For the calculated angles the constants $a : b : c = 1.0934 : : 0.5894$, $\beta = 74° 09'$, are taken. These values, from Goldschmidt's Winkeltabellen, are almost identical with the values given for pyroxene in Dana's System of Minearalogy, 6th edition, 1892, p. 352.

All four faces of the negative pyramid *s*{$\bar{1}$11} are strongly etched, only incomplete narrow rims of the bright shining face being left, but these gave fairly good reflections. This pyramid is the only terminal face that could be found on either crystal.

The unit prism *m* is generally smaller than the pyramid *s*, though one face of *m* was nearly as large. The true value of the prism angle is probably a few minutes larger than the average value here given (43° 37′), as out of 10 measurements six lie between 43° 39′ and 43° 43′, but two low values slightly lower the general average.

The clinopinacoid, *b*{010}, is present as small faces, smaller than those of *a*{100}, *m*{110}, or *s*{$\bar{1}$11}, but generally larger than any of the other faces.

All the remaining forms are present as line faces in the prism zone. Of the known forms *Δ*{150} was noted but once as a small broad line face. Three faces of *g*{210} were measured on the second crystal, the faces being exceedingly fine striæ and the reflections very poor. In one no reflection could be seen. The three measured values are: 62° 00′, 63° 56′, 63° 19′; calculated, 62° 15′.

The new forms are two in number and are briefly described below:

**θ*{230}. Only one face of this form, a line face, was observed on the first crystal. It lay between *a* and *m* and was the only face in this quarter of the prism zone besides *a m b*. The reflection was faint but distinct. Two measurements of it gave the values 32° 05′ 32° 13′. The calculated value is 32° 22′.

**Γ*{530}. One face of *Γ* was noted on each crystal. The faces were all line faces and gave poor reflections, though the one from the first crystal (57° 47′) was very distinct and the difference between the measured and calculated angles is very slight. The measurements were 57° 47′ and 58° 30′; the average is 58° 09′, and the calculated value 57° 45′. A third face gave a measured angle of 59° 13′, and may possibly belong to this form.

Reflections were also measured from several other faces which agreed approximately for {320} and {520}, but they were too poor to warrant any further characterization.

The combination *a*{100}, *m*{110}, *b*{010}, and *s*{$\bar{1}$11}, with a tabular habit due to the predominance of *a*{100} seems to be characteristic of these brownish-violet titanium-rich basaltic augites.

CUPRODESCLOIZITE FROM CALIFORNIA.

Some samples of reported vanadium ore, sent to the United States Geological Survey by Messrs. A. L. Lombard and J. F. Main, of the Dirigo Mining & Milling Co., of Los Angeles, Cal., proved to be coated with a deposit of cuprodescloizite. The associated lead minerals are cerusite and vanadinite, and from these the cuprodescloizite seems to be derived. The locality is given as Camp Signal, in San Bernardino County, Cal.

A qualitative chemical test showed the presence in quantity of lead, copper, zinc, and vanadium, and of a little water. A direct quantitative determination of the vanadium gave 21 per cent V_2O_5.

The material, when examined under the microscope, was seen to be well crystallized in minute plates. Some of these were square or oblong; others were irregularly shaped. The rectangular plates gave parallel extinction, with the axial plane parallel to one of the sides, and with a very large axial angle. The plates are colorless or pale yellow. The thicker pieces are very slightly pleochroic in shades of yellow. The double refraction was not very high. A few tabular pieces showed an acute termination, the sides of which were inclined 52° to the trace of the axial plane. The sections, tabular parallel to $a\{100\}$, showed $c\{001\}$, $u\{011\}$, both large, and $b\{010\}$ small.

These various data are all in harmony with the properties of descloizite and cuprodescloizite, to which the mineral is therefore referred.

MINERALOGY OF THE FRENCH PHOSPHORITES.

INTRODUCTION.

In two recent publications,[1] Lacroix has described the mineralogy of the phosphorites of France and its colonies. These descriptions present so clearly the mineralogical composition of the phosphorites that I thought it would be of interest to students of the American phosphate deposits to present briefly the results reached by Lacroix. The data here given are, therefore, a free translation and compilation of his papers.

TYPES OF PHOSPHORITES.

The French phosphorites are of three types—

(1) Holocrystalline, fibrous; (2) amorphous (isotropic), homogeneous; (3) mixture of the amorphous and holocrystalline.

(1) The holocrystalline, fibrous type is composed of either dahllite or francolite. Dahllite is a hydrous carbonate and phosphate of lime, free from fluorine, and was first found in Norway, its occurrence there being described by Brögger and Bäckstrom [2] in 1888. Tschirwinsky's podolite, described [3] as a new mineral in 1907, is probably identical with dahllite.[4] Francolite was described in 1850 from Tavistock, Devonshire, England,[5] but has hitherto been considered a variety of apatite. Staffelite [6] is considered by Lacroix as identical with francolite, but the name is kept for the fibrous variety of francolite. Damour's hydroapatite [7] also is francoline. Francolite is similar to dahllite in composition, but contains a notable amount of fluorine.

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[1] Lacroix, A., Sur la constitution minéralogique des phosphorites françaises: Compt. Rend., vol. 150, 1910, p. 1213; Minéralogie de la France, vol. 4, second part, 1910, p. 555.

[2] Brögger, W. C., and Bäckstrom, H., Dahllite, a new mineral from Odegarden, Bamle, Norway: Abstracted in Zeitschr. Kryst. Min., vol. 17, 1890, p. 426; also in Dana's system of mineralogy, 6th ed., 1892, p. 866.

[3] Tschirwinsky, W., Podolite, a new mineral: Centralbl. Min. Geol. Pal., 1907, p. 279. For some earlier but incomplete descriptions in Russian publication, see abstract thereof in Zeitschr. Kryst. Min., vol. 46, 1909, p. 296.

[4] Lacroix, op. cit. See also the following paper in this volume.

[5] Henry, T. H., On francolite, a supposed new mineral: Philos. Mag., vol. 36, 1850, p. 134. The CO_2 present in the mineral was not detected by Henry. A better analysis of francolite from Cornwall was later given by Story-Maskelyne, N., and Flight, W., Mineralogical notes—3, Francolite, Cornwall: Jour. Chem. Soc. (London), vol. 24, 1871, p. 3.

[6] Stein, C. A., Ueber das Vorkommen von phosphorsauren Kalk in der Lahn- und Dill-gegend mit besonderer Berücksichtigung des Vorkommens bei Staffel, Amts Limburg: Jahrb. Ver. Naturk. Herzogthum Nassau, vols. 19-20, 1864-1866, p. 41. Abstracted in Jahrb. Min., 1866, p. 716.

[7] Sur l'hydro-apatite, espèce minérale: Annales des mines, vol. 10, 1856, p. 65.

(2) The amorphous, perfectly isotropic type is composed of the mineral collophanite, which is a hydrous carbonate and phosphate of lime, generally free from any appreciable amount of fluorine, but rarely containing a small amount (fluocollophanite).

(3) The third type is composed of the following minerals, in variable amounts:

(*a*) Dahllite; (*b*) francolite (var. staffelite); (*c*) an unknown mineral, similar to dahllite and francolite in chemical composition but differing optically from them; (*d*) collophanite.

This type of phosphorite, composed of an amorphous mineral and one or more crystalline minerals, is called quercyite. If the unknown mineral ((*c*) above) is absent, the subtype is called α–quercyite; if the unknown mineral is present, the subtype is called β–quercyite. Quercyite is often formed of alternating layers of α–quercyite and of β–quercyite.

DESCRIPTION OF MINERALS.

DAHLLITE.

Dahllite occurs as fibrous crusts, stalactites, or concretions with a radiating or confused fibrous structure, and also in a pure state as nodular masses and concretions, some resembling the fungus polypore having formed against the sides of pockets in the phosphorite. It is colorless, white, yellow, or greenish, and is transparent in thin pieces. The streak is white, and the luster vitreous, dull, silky, or slightly greasy in the very pure specimens. The fibrous concretions are very tenacious. The fracture yields a dull white surface, sometimes showing a regular fibrous structure, but more often the fibers are radiating or intermingled. From the similarity of the shape of the nodular masses of dahllite, quercyite, and collophanite, the dahllite may have formed by the dehydration of the quercyite or the collophanite.

Optically the mineral is hexagonal, uniaxial, and negative, the fibers being elongated parallel to the least index of refraction. It shows the helicoidal optical grouping. The birefringence is slightly greater than that of apatite. The mean refractive index $(n) = 1.625$ approximately; the hardness is 5, and the density ranges from 2.97 (on confused fibrous masses more or less porous) to 3.053. When heated in a closed tube, it decrepitates without fusion, giving off water. It is readily soluble in cold dilute acids, with evolution of CO_2. The formula is given as $2Ca_3(PO_4)_2.CaCO_3.\frac{1}{2}H_2O$, but is more probably $3Ca_3(PO_4)_2.CaCO_3.H_2O$. See discussion in the following papers in this volume. For analyses see the table at the end of this paper.

FRANCOLITE.

Francolite is found as minute hexagonal crystals showing the forms *c* {0001} and *m* {10$\bar{1}$0}. These are tabular, flattened parallel to *c* {0001}, and are generally grouped in rosettes or confused masses. More frequently it forms the fibrous variety staffelite, as mammillated fibrous crusts or as very pure spherolites which were formerly considered to be apatite. These spherolites occasionally show minute crystals, about 1 millimeter in length, with free ends. They are colorless, white, yellow, or greenish, with a vitreous luster which tarnishes or becomes dull on exposure to air, the specimens changing from translucent to opaque. The streak is white.

The hexagonal crystals show a division of the basal section into six sectors, each normal to an acute negative bisectrix, the trace of the large axial angle being, in each sector, parallel with the prism edge. By superposition of biaxial plates the crystals often appear uniaxial. The birefringence is, like that of dahllite, 0.004 to 0.005, and the mean refractive index $(n) = 1.625$ approximately. The hardness is 4 to 5, and the density 3.09 to 3.128. In its pyrognostic and chemical properties, it is similar to dahllite, except that it shows the presence of fluorine. The formula given for it is $(CaF)_2Ca_8(PO_4)_6 . CaCO_3 + H_2O$. Analyses are given at the end of this paper.

UNKNOWN MINERAL.

The unknown mineral, mentioned as forming the characteristic component of β-quercyite, has not been found in a pure state, so that its chemical composition is not accurately known, but from analyses of specimens of β-quercyite rich in this unknown mineral (analyses Nos. 11 and 12 of this paper), its composition is doubtless near that of dahllite and francolite. The distinguishing test, however, is its optical character, for it is positive while both dahllite and francolite are optically negative. The birefringence of this positive mineral is about double that of the negative ones.

COLLOPHANITE.

The amorphous mineral collophanite forms concretionary masses, resembling opal or gum, and has a conchoidal fracture. An earthy variety is called monite. Some of the nodules or masses are nearly transparent, and others are only translucent, but most of them are opaque. The nearly transparent kind looks like carnelian stone, the others more like enamel. It is colorless, white, yellow, brown, or reddish. It has a vitreous luster, a little resinous or earthy in the variety monite. It is isotropic. The index of refraction is not constant for different specimens. Two different samples gave for sodium light the values 1.569, 1.612. The hardness is 4.5, and the density of the common variety 2.69–2.82, though that of monite is as low as 2.1. One variety is very poor in or entirely free from fluorine; a second variety (fluocollophanite) contains fluorine ranging up to an amount, in proportion to the P_2O_5 content, equal to that present in apatite. Its pyrognostic and chemical properties are like those of the crystallized compounds. Collophanite is often impure from admixed substances. It may be distinguished from similar minerals, such as opal, by its ready solubility in acids with evolution of CO_2, and by its P_2O_5 reaction. The formula given for it is $x[Ca_3(PO_4)_2]$ or $x[(CaF)_2Ca_8(PO_4)_6] + yCaCO_3 + zH_2O$. See following papers. Analyses are given at the end of this paper.

QUERCYITE.

The name quercyite is applied to mixtures of the amorphous collophanite and the crystalline dahllite, francolite, and the unknown mineral. The most common type of the French phosphorites is this variable mixture called quercyite. Only a small portion of the phosphorites are composed of either collophanite or one of the crystallized phosphates. The mixture in quercyite is so intimate that it is impossible to separate the constituents mechanically. If the crystalline mineral present is optically negative the mixture is called α-quercyite; if the unknown mineral (optically positive) is present, the mixture is called β-quercyite. Quercyite is often composed of alternating layers of α- and β-quercyite. Some of the layers may be nearly free of any crystalline material when they are composed of only collophanite. The density of α-quercyite is 2.83 to 2.87, and the mean refractive index about 1.608.

SUMMARY OF PROPERTIES.

This completes the list of minerals forming the French phosphorites. For convenience their chief diagnostic properties, including those of α-quercyite and of fluorapatite, are here tabulated:

Properties of phosphorite minerals.

	Dahllite.	Francolite.	Unknown mineral.	Collophanite.	α-Quercyite.	Fluorapatite.
Density	2. 97–3. 05	3. 09–3. 13	(?)	2. 69–2. 82	2. 83–2. 87	3. 2
Mean refractive index	1. 625	1. 625	(?)	1. 569–1. 612	1. 608	1. 63
Birefringence	0. 005 (approx.).	0. 005 (approx.).	0. 009 (approx.).	0. 000	0. 005	0. 004
Optical character	Negative.	Negative.	Positive.	Isotropic.	....	Negative.
Distinguishing chemical component	CO_2,H_2O	F,CO_2,H_2O	(?)	CO_2,H_2O	F,CO_2,H_2O	F.

CHEMICAL COMPOSITION.

The chemical composition of the minerals and of their mixture—quercyite—can be seen by the analyses given below. They have been grouped together in this way in order to render the comparison more easy.

Dahllite analyses.....	1. Original analysis, Bamle, Norway.
	2. Mouillac, Quercy, France.
	3. Podolite, crystals, Podolie, Russia.
	4. Podolite, crystalline aggregate, Podolie, Russia.
Francolite analyses...	5. Cornwall, England.
	6. d'Encourtiech, Ariège, France.
	7. Staffelite, Staffel, Limburg.
Collophanite analyses.	8. Original analysis, Sombrero, Antilles.
	9. Pouzillac, Gard, Cévennes, France.
Quercyite analyses....	10. α-quercyite, Mouillac, Quercy, France.
	11. β-quercyite, Mouillac, Quercy, France.
	12. β-quercyite, Castillo de Belmez, Cordone, Spain.

Analyses of phosphorite minerals.

	Dahllite.				Francolite.			Collophanite.		Quercyite.		
	1	2	3	4	5	6	7	8	9	10	11	12
CaO	53.00	53.65	51.15	51.31	54.09	52.32	54.67	50.70	49.73	51.85	50.45	52.50
P_2O_5	38.44	38.40	39.04	36.44	38.14	40.00	39.05	39.10	37.40	37.60	36.60	37.75
F	....	Trace.	.00	.26	3.34	3.36	3.05	....	.88	1.50	.83	Trace.
CO_2	6.29	5.30	3.90	4.18	2.25	5.30	3.19	3.96	3.75	4.00	4.62	5.70
H_2O	1.37	2.10	(?)	(?)	1.59	....	1.40	5.02	7.05	4.80	6.00	3.20
$(Al,Fe)_2O_3$	....	.57	3.04	2.19	.91	.43	.06	....	.50	....	1.30	.85
MgO	[a].79	....	....	....	....	....	.69	.80	....	....	....	....
$(K,Na)_2O$	1.00	....	....	1.11	....	....	....	....	.30	....	....	....
Organic	....	....	....	.56	....	....	....	....	....	....	....	....
SiO_2 (insoluble)	....	....	....	4.87	....	....	....	....	....	....	....	....
	100.89	100.02	97.13	100.92	101.01	101.41	101.42	99.58	99.61	99.75	99.80	100.00
Less O for F	....	....	....	.11	1.41	1.41	1.28	....	.37	.63	.35	....
	....	....	....	100.81	99.60	100.00	100.14	....	99.24	99.12	99.45	....

[a] FeO.

THE PROBABLE IDENTITY OF PODOLITE WITH DAHLLITE.

A comparison of the properties and chemical composition of podolite and dahllite shows them to be essentially identical. Dahllite was described in 1888 by Brögger and Bäckström,[1] and podolite by Tschirwinsky [2] in 1907, and the summary of the properties of the two minerals given below has been prepared from the printed descriptions.

Properties of dahllite and podolite.

Dahllite.	**Podolite.**
Occurs in crusts with fibrous structure, on apatite.	Occurs in crystalline masses or in prismatic crystals on phosphorite, also in spherulites of prismatic crystals.
Density is 3.053.	Density is 3.077.
Color is pale yellowish white.	Color is yellowish.
Uniaxial, negative.	Apparently hexagonal, crystals show optical anomalies, negative.
Double refraction and index of refraction slightly greater than that of apatite.	Double refraction somewhat greater than that of apatite.
Soluble in cold dilute acid with evolution of CO_2.	Mean index of refraction 1.635.
	Soluble in HCl with evolution of CO_2.
Composition..... $\begin{cases} H_2Ca_{14}P_8C_2O_{39} \text{ or} \\ 2Ca_3P_2O_8.CaCO_3.\frac{1}{2}H_2O \end{cases}$	Composition..... $\begin{cases} Ca_{10}P_6CO_{27} \text{ or} \\ 3Ca_3P_2O_8.CaCO_3 \end{cases}$

To better compare the two formulas, they are given below with Ca given in constant amount.

Dahllite..	$H_{10}Ca_{70}P_{40}C_{10}O_{195}$
Podolite..	$Ca_{70}P_{42}C_7O_{189}$

The analyses of the two minerals are shown in the following table for comparison:

---

[1] Brögger, W. C., and Bäckström, H., Dahllite, a new mineral from Odegarden, Bamle, Norway. Abstracted in Zeitschr. Kryst. Min., vol. 17, 1890, p. 426; also in Dana's System of mineralogy, 6th ed: 1892, p. 866.

[2] Tschirwinsky, W., Podolite, a new mineral: Centralbl. Min., Geol. u. Pal., 1907, p. 279; abstracted in Zeitschr. Kryst. Min., vol. 46, 1909, p. 296.

Analyses of dahllite and podolite.

	Dahllite.	Podolite.	
		Crystals.	Crystalline aggregate.
CaO	53.00	51.15	51.31
P_2O_5	38.44	39.04	36.44
CO_2	6.29	3.90	4.18
H_2O	1.37	Not det.	Not det.
Fe_2O_3	[a].79	3.04	1.73
Al_2O_3			.46
K_2O	.11		.45
Na_2O	.89		.66
F		.00	.26
Organic			.56
SiO_2			4.87
Total	100.89	97.13	100.92

[a] FeO.

The above figures show the undoubted identity of the three substances analyzed. The CO_2 values for podolite are slightly lower than that given for dahllite, but the differences are slight. Water was not determined, but it must unquestionably have been present, for such a secondary mineral as podolite would be very likely to contain some, and a small amount, at least, must have been absorbed by the ground sample. The poor summations and the varying values in general lead one to suspect that further analyses of purer material, carefully made, would lead to slightly different results.

THE COMPOSITION OF THE PHOSPHORITE MINERALS.

INTRODUCTION.

The previous paper on the mineralogy of the French phosphorite deposits contains several analyses of these minerals, which, with those already published, furnish sufficient criteria for a determination of their formulas. I have therefore calculated the ratios from the different analyses and by averaging them up, have deduced formulas for the minerals in question. Below the actual ratios obtained, I have given them with CaO taken as 100.

DAHLLITE.

From analyses 1 to 4, given on page 95, the following ratios are obtained:

Ratios from dahllite analyses.

	1	2	3	4
CaO	0. 945	0. 956	0. 912	0. 915
P_2O_5	. 271	. 270	. 275	. 256
CO_2	. 143	. 120	. 090	. 095
H_2O	. 076	. 117	(?)	(?)
CaO	100	100	100	100
P_2O_5	29	28	30	28
CO_2	15	13	10	10
H_2O	8	12	(?)	(?)

The average values of these yield the formula

$$100(CaO).\ 29(P_2O_5).\ 12(CO_2).\ (10H_2O),$$

which is sufficiently close to the simple one

$$10CaO.\ 3P_2O_5.\ CO_2.\ H_2O.$$

to suggest strongly that this is the correct formula for dahllite.

FRANCOLITE.

From analyses 5 to 7, given on page 95, the ratios shown below are deduced:

Ratios from francolite analyses.

	5	6	7
CaO	0.964	0.933	0.974
P_2O_5	.269	.282	.275
F	.176	.177	.161
CO_2	.051	.084	.072
H_2O	.088	.088	.078
CaO	100	100	100
P_2O_5	28	30	28
F	18	19	17
CO_2	5	9	8
H_2O	9	9	8

The average of these values gives—

$$100(CaO).\ 29(P_2O_5).\ 18(F).\ 7(CO_2).\ 9(H_2O)[\text{minus } 9O],$$

which reduces to the simpler formula

$$10(CaO).\ 3(P_2O_5)\ 2(F).\ (CO_2).\ (H_2O)\ [\text{minus } 1O],$$

which may be written

$$9CaO.\ 3P_2O_5.\ CO_2.\ H_2O.\ CaF_2.$$

The average ratio of P_2O_5 to CaO is 3 to 10.44, being for analysis No. 5, 3 to 10.75; for analysis No. 6, 3 to 9.93; and for analysis No. 7, 3 to 10.63. This value lies almost exactly halfway between the 3:10 ratio required by my formula above and the 3:11 required by Lacroix's formula for francolite.

COLLOPHANITE.

From the values given in analyses 8 and 9, on page 95, the following ratios are deduced:

Ratios from collophanite analyses.

	8	9
CaO	0.904	0.886
P_2O_5	.275	.263
F	....	.046
CO_2	.090	.085
H_2O	.279	.392
CaO	100	100
P_2O_5	30	30
F	....	5
CO_2	10	10
H_2O	31	44

The average formula developed is

$$10CaO.\ 3P_2O_5.CO_2.\ 3+\ H_2O(+F?).$$

SUMMARY.

The three formulas developed are repeated here in order to show their relation to one another. To the list are added those of apatite, both the fluoapatite and the hypothetical hydroxyapatite.

Dahllite	$9CaO.3P_2O_5.CaO.\ CO_2.H_2O.$
Francolite	$9CaO.3P_2O_5.CaF_2.CO_2.H_2O.$
Collophanite	$9CaO.3P_2O_5.CaO.\ CO_2.H_2O+nH_2O.$
Fluoapatite	$9CaO.3P_2O_5.CaF_2.$
Hydroxyapatite	$9CaO.3P_2O_5.CaO.\ H_2O.$

The derivation of dahllite from the dehydration of collophanite becomes very simple, proceeding according to the reaction,

$$\underset{\text{(Collophanite)}}{9CaO.3P_2O_5.CaO.CO_2.H_2O.nH_2O} = \underset{\text{(Dahllite)}}{9CaO.3P_2O_5.CaO.CO_2.H_2O} + nH_2O.$$

By the introduction of fluorine, the reaction would yield francolite instead of dahllite:

$$\underset{\text{(Collophanite)}}{9CaO.3P_2O_5.CaO.CO_2.H_2O.nH_2O} + 2HF = \underset{\text{(Francolite)}}{9CaO.3P_2O_5.CaF_2.CO_2.H_2O} + nH_2O.$$

NATRAMBLYGONITE FROM COLORADO.

OCCURRENCE.

The mineral described in this paper was collected by me in 1908 in a large pegmatite mass 4 miles northwest of Canon City, Colo. The presence of lithium minerals—lepidolite and pink tourmaline—had been noted in this pegmatite by Sterrett [1] and it was through his kindness and that of Mr. J. D. Endicott, of Canon City, that I was enabled to visit the locality and collect a suite of specimens from the pegmatite. As described by Sterrett, the tourmaline and associated minerals occur on a low, oval hill composed of pegmatite inclosed in contorted biotite and hornblende gneiss. Pink tourmaline and lepidolite are abundant, though no cavities or pockets affording gem tourmaline were seen, the mineral being found only in the solid pegmatite.

ASSOCIATION.

The minerals associated with natramblygonite are few in number and do not possess any unusual properties. Tourmaline is abundant in black, pink, or green crystals, though no faces except those in the prism zone were seen on any of the crystals collected. A dark-green, nearly black core with a pink shell seems to be a common color association for this locality. Small masses of minute bluish crystals, and some larger green ones embedded in muscovite, were also noted. Most of the tourmaline is opaque and partly altered. The micas, muscovite and lepidolite, are also abundant. Lepidolite occurs in scaly pink masses, also as larger plates and in indefinite crystalline aggregates of pink or purplish colors. Albite generally is tabular in platy masses or in groupings of small crystals. The quartz and potash feldspars are massive and the original piece of natramblygonite, now deposited in the United States National Museum, is also massive. The mineral has recently been found in well-developed crystals.

DESCRIPTION OF MINERAL.

The specimen of the mineral measures about 5 by 7 by 3 centimeters and consists of a mass of cleavable natramblygonite surrounded by feldspar and lepidolite. Small veins and isolated masses of lepidolite are scattered through the new mineral. Small amounts of pink tourmaline and of albite were also detected embedded therein.

Three directions of cleavage can be detected, one more prominent than the other two. A section of the mineral cut parallel to the most prominent cleavage showed the other two cleavages intersecting at about 70°. In its general appearance the mineral resembles massive amblygonite very much. The hardness is 5.5, and determinations of the specific gravity varied from 3.01 to 3.06, with an average value of about 3.04. The luster is vitreous, inclining slightly to greasy. The color is grayish white to white. In the hand specimen it is translucent to opaque.

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[1] Sterrett, D. B., The production of precious stones in 1908: Mineral Resources United States for 1908, U. S. Geol. Survey, 1909, p. 44.

Examined in thin section under the microscope, inclusions of quartz, feldspar, and mica can be seen, and also an irregular distribution of a kaolin-like dust. Two directions of polysynthetic twinning lamellæ intersecting at about 86° are prominent, and lie at an angle against the cleavage cracks. The best cleavage is nearly normal to a bisectrix, and the section parallel to this cleavage shows a biaxial interference figure with a large angle. The optical sign of the mineral is negative. Its mean refractive index lies near 1.60.

Heated in a blowpipe flame the mineral easily fuses, without decrepitation but with slight intumescence to an opaque white enamel, The flame is yellow with no indication of the red characteristic of lithium. In this particular natramblygonite differs markedly from amblygonite, and can thereby be distinguished from the common mineral. It would be well to test amblygonite from different localities by this flame test. Heated in a closed tube, water is given off and the mineral then quietly fuses without decrepitation to a blebby enamel firmly fused to the glass tube.

CHEMICAL COMPOSITION.

Analysis of a selected sample of natramblygonite gave the values shown below. The sample was finely crushed and all visible impurities and doubtful pieces picked out by hand under a magnifying glass. All of the final sample sank in a Thoulet solution of density 3.01+ and floated in solution of density 3.06. Beryllium was tested for but could not be detected. The mineral is difficultly soluble in H_2SO_4, in which solution no calcium could be found.

Analysis and ratios of natramblygonite.

	Per cent.	Ratio.	
P_2O_5	44.35	0.312	1.00
Al_2O_3	33.59	.329	1.06
Li_2O	3.21	.107	.93
Na_2O	11.23	.181	
K_2O	.14	.001	
H_2O+	4.78	.266	.85 1.32
F	5.63	.296	.47
	102.93		
Less O for F	2.37		
	100.56		

The ratios yield the formula $P_2O_5.Al_2O_3.(Na,Li)_2O.(H_2O,F_2)$ which may be written more simply $AlNa(OH)PO_4$, with the Na partly replaced by Li and the (OH) by F. The ratios for water and fluorine are a little high, probably due to the difficulty of the fluorine determination. It is worthy of note, however, that the ratios for water and fluorine are all high in Penfield's analyses of amblygonite.[1] The relations of natramblygonite to amblygonite are clear, the first being essentially the sodium mineral and the second the lithium one:

Natramblygonite, $Na[Al(OH,F)]PO_4$.
Amblygonite, $Li[Al(OH,F)]PO_4$.

Nothing was seen which would indicate that the new mineral here described was originally the lithium compound and was afterward changed to the sodium one. The alteration of amblygonite, described by Carnot and Lacroix,[2] yielded the mineral morinite, which contains lime and soda, without any lithia, and much more water and fluorine than was present in the amblygonite.

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[1] Penfield, S.L., On the chemical composition of amblygonite: Am. Jour. Sci., 3d ser., vol. 18, 1879, pp. 295.

[2] Carnot, A., and Lacroix, A., The chemical composition of morinite: Bull. Soc. franç. minéralog., vol. 31, 1908, p. 149.

THE PROPERTIES OF MOSESITE.

GENERAL DESCRIPTION.

The name mosesite was proposed by Canfield, Hillebrand, and Schaller, for a mercury mineral, described by them,[1] from Texas, in honor of Prof. Alfred J. Moses, of Columbia University, New York, who first definitely described the interesting mercury minerals at Terlingua, Brewster County, Tex.

In the general description of the mineral Mr. Canfield states that the small yellow crystals, associated with montroydite, were perched on calcite crystals, on which they appeared to lie with but little or no bond. The slightest touch would loosen them, leaving no scar upon the calcite, but merely a clean spot. A careful search revealed 26 crystals, 22 of which are simple octahedrons and the others spinel twins. No other forms were observed, and none of the mineral was massive. A second specimen showed hundreds of crystals scattered over a surface of calcite measuring 4 by 6 centimeters, which rests upon the pinkish rock characteristic of the Terlingua specimens. Canfield gives the following description of these crystals:

> Nearly all of the crystals are spinel twins. They are frequently grouped together in confused masses; one polysynthetic twin—a 5-ling—was seen. Simple octahedrons are rare. None was modified by other forms. No other mercury mineral is present in the specimen unless some delicate, elongated, light-yellow particles should prove to be kleinite.
>
> There are no indications that the crystals are affected by the light. If light affects the color, it must act very slowly. The color of those crystals which are so situated as to have some protection from the light is exactly like that of the most exposed. No difference in color could be noted between the surface and the interior of the crystals. Most of the crystals are translucent. The largest crystal found is brilliant and transparent and measures 0.5 millimeters along its edge. Generally the faces of the crystals are bright and uneven. They are very brittle, with signs of cleavage.[2] The fracture is uneven. The hardness slightly exceeds that of calcite. The mineral crumbles to a powder under the pressure required for this test. No piece could be obtained that was large enough to determine the density. The luster is adamantine. The color is a rich lemon to a canary yellow. The streak and powder are a very pale yellow.

CHEMICAL PROPERTIES.

Mr. Canfield gives the following description of the chemical properties of the mineral:

> When heated gradually to a low temperature in a closed tube, the assay turns to a dark reddish brown, almost black. As the heat increases the color changes rapidly

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[1] Canfield, F. A., Hillebrand, W. F., and Schaller, W. T., Mosesite, a new mercury mineral from Terlingua, Tex.: Am. Jour. Sci., 4th ser., vol. 30, 1910, pp. 202-208.

[2] The cleavage is imperfect octahedral.—Schaller.

to white, but without changing the form of the original crystals. Fumes of calomel are given off and condense in the tube. Many globules of mercury collect in the tube beyond the coating of calomel. Continued heating soon causes the assay to volatilize and disappear. If a fresh fragment of the mineral is heated rapidly in the closed tube it decrepitates violently, almost explosively, then it fuses and volatilizes.

In cold hydrochloric acid the mineral is changed slowly to a white substance, which retains the original form. If the acid is hot, the change is more rapid but the product is the same.

Dr. W. F. Hillebrand examined the material chemically and found that—

> So far as the very scanty material permitted of ascertaining, the composition of mosesite approaches that of kleinite; that is, it is a mercury-ammonium compound containing chlorine and the sulphate group besides a little water. Determinations made on 0.04 gram of material gave 5 per cent Cl and 3.5 per cent SO_4. The former amount is considerably lower and the latter somewhat higher than in kleinite, but the values are no more than approximations. There is, however, one marked chemical difference, which will be considered later.
>
> Spectroscopic tests that were kindly made by Dr. P. G. Nutting, at the Bureau of Standards, showed prominent mercury and nitrogen spectra and also the red line of hydrogen, the last being ascribed by him to water vapor. A singular feature of the behavior in vacuo was the immediate appearance, when the current was turned on and before the application of heat, of a mercury spectrum.
>
> The mineral was at the time not between the electrodes, but far to the rear of one of them, at the sealed end of the Plucker tube. Under these conditions the color of the mineral fragments underwent a pronounced and permanent change from bright yellow to a yellowish gray. With a minute crystal of kleinite there was a mere indication of the mercury lines before heating, and no color change was observed. As soon as the temperature of mosesite was raised to visible incipient decomposition, the spectra of both nitrogen and mercury became brilliant. As mentioned by Mr. Canfield, mosesite does not seem to undergo the color changes in sunlight and darkness that appear to be characteristic of the deeper-colored crystals of kleinite.
>
> When heated in a narrow tube closed at one end, the color changes and the sublimates were much like those afforded by kleinite, and there was the same liberation of an active gas that set free iodine from potassium iodide. Ammonium bromide liberated ammonia as from kleinite.
>
> The behavior toward hydrochloric acid, noticed by Mr. Canfield, affords a certain chemical means of distinguishing mosesite from kleinite where only these two are concerned. When covered with concentrated hydrochloric acid mosesite is entirely decomposed in a few hours, with separation of a coherent white material that shows the behavior of calomel. The solution contains the sulphate and ammonium groups, besides much mercuric mercury. Kleinite, on the other hand, shows no perceptible change for a long time, but in the course of 48 hours a minute crystal of it was almost entirely decomposed. There remained only a whitish residue that looked as if it might be the claylike matter that is such a persistent contaminant of the mineral. It was free from calomel.
>
> It will be remembered that the chemical evidence points to kleinite being a mixture or solution of mercury-ammonium chloride with a mercuric sulphate and perhaps chloride. There would seem to be an association of similar general character in mosesite, but with a mercurous sulphate or chloride replacing in part or wholly the corresponding mercuric salts of kleinite.

CRYSTALLOGRAPHY.

In studying the crystallography and optical properties of mosesite, I found that the crystals are apparently octahedra of the isometric system. Twinning on the spinel law has been observed several times; when this occurs, the crystals of mosesite are very commonly flattened parallel to a pair of octahedral faces. Mr. Canfield has mentioned a 5-ling, a spinal twin repeated five times.

The faces of the crystals are never smooth. Though bright and often highly polished, they are uneven, and only a few of the faces give a single reflection. Most of the faces when measured on the goniometer give a number of signals, no particular one of which is brighter than the others. This condition has rendered accurate determination of the form of the crystals impossible. An additional feature that has rendered accurate measurements difficult is the tendency for a number of crystals to grow together, some in nearly parallel position and others at widely different angles. A mass of signals, therefore, resulted from examining such groups of mosesite on the goniometer, and on the minute crystals that were available it was not possible to know what signals to measure and what ones to exclude. Where only two or three faces were measured in a zone, it was well-nigh impossible to be sure of having the zone accurately centered. The measurements, the occurrence of (probable) spineltwins, and the optical relations about to be described make it fairly certain that the crystals of mosesite are in reality octahedra. No form other than the octahedron was observed.

On part of a spinel twin, the faces of which gave a mass of very poor reflections, there were measured:

$o \wedge o'$	=68°	70° 32′ calculated.
	=68° (cleavage face)	70° 32′ calculated.
	=68° 28′	70° 32′ calculated.
$o \wedge \varrho$	=41° 13′	38° 56′ calculated.

A second crystal, also a spinel twin, gave:

$o \wedge o'$	=108° 54′	109° 28′ calculated.
	=107° 53′	109° 28′ calculated.
	= 71° 38′	70° 32′ calculated.
	= 70° 47′	70° 32′ calculated.
	= 68° 51′	70° 32′ calculated.
	= 72° 28′	70° 32′ calculated.
$o \wedge \varrho$	= 37° 06′	38° 56′ calculated.
	= 38° 56′	38° 56′ calculated.

A third crystal was adjusted as closely as possible in polar position for two-circle measurement and on revolving the crystal, the four octahedral faces were seen to lie in the positions required for the form {111}.

From the above data, meager and poor as they are, the isometric character of the crystals is deduced, especially as this is supported by the investigation of the optical properties.

OPTICAL PROPERTIES.

Under the microscope mosesite is pale yellow, nonpleochroic, and seems to possess a moderate double refraction. When a fragment is crushed many of the resultant pieces have a triangular or rhombic shape, due to the octahedial cleavage. When a fragment of fluorite was crushed and examined under the microscope similar effects were seen, though the cleavage was much better developed.

The crystallographic measurements have shown that the crystals are in all probability isometric octahedra and should, therefore, be isotropic when examined under the microscope with crossed nicols. Such an examination, however, shows the mineral not to be isotropic, but doubly refracting. On heating the mineral to 186°, the crystals lose their double refraction and become isotropic. Mosesite is therefore dimorphic, the isometric optical condition that agrees with the geometrical form being stable only above 186°, the mineral changing to the dimorphous doubly refracting condition at temperatures below 186°.

As examined at ordinary temperatures, the sections show great similarity to kleinite. Much of the material does not extinguish at all; other parts extinguish four times during a complete revolution of the stage, and the interference colors are brilliant. On crushing a fragment between two glass slides and examining the very small particles, they are seen to be nearly colorless, and, unlike the larger pieces, isotropic. It seems that the local heat developed by the crushing is sufficient to heat these small particles to at least 186° and cause their reversion to the isotropic state.

Seven different fragments were heated on glass slides in an air oven to the temperatures given and with the results shown in the following table:

Effect of heating mosesite.

No. of slide.	Temperature. °C.	Effect.	Probable temperature of change.
1	150	No change; mineral still doubly refracting.	
	200	Brown and isotropic.	150–200°.
2	160	Brown and doubly refracting.	
	167	Doubly refracting.	
	180	Doubly refracting.	
	189	Isotropic.	180–189°.
3	169	Doubly refracting, but section too opaque for further study.	Above 169°.
	190		

Effect of heating mosesite—Continued.

No. of slide.	Temperature.	Effect.	Probable temperature of change.
	° *C.*		
4	169	Doubly refracting.	
	184	Doubly refracting.	
	186	Nearly isotropic.	
	190	Isotropic.	186–190°.
5	184	Doubly refracting.	
	186	Nearly isotropic.	
	188	Nearly isotropic.	
	190	Isotropic, except for a few minute doubly refracting spots.	184–186°.
6	186	Doubly refracting.	
	192	Still doubly refracting in places, but partly isotropic. This particular piece may have been thicker than the others, and therefore did not revert so readily.	186–192°+.
7	186	Isotropic on thin edges, but doubly refracting in thicker center.	
	192	Isotropic.	186–192°.

From these data the temperature of reversion to the isotropic isometric state probably lies between 180° and 190° and is taken as 186°. If the "molecular inertia" of mosesite is considerable, as is the case with kleinite,[1] then this temperature, 186°, is probably a little high. On cooling, the isotropic mineral does not immediately again become doubly refracting. Examination after 24 hours shows the mineral to be still isotropic. The change back seems to be, like that of kleinite, a very slow one, but doubtless it is gradually taking place. A section of kleinite described by Hillebrand and Schaller[2] as almost entirely reverted after 30 months is now, after 4 years, completely changed back to its original doubly refracting condition.

The optical similarities shown by these two minerals, coupled with their evident chemical relationship, suggested trying the effect of heating kleinite to the reversion temperature of mosesite (186°). When this was done, kleinite[3] became optically isotropic, like mosesite. The results of the experiments are shown in the table below:

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[1] Hillebrand, W. F., and Schaller, W. T., The mercury minerals from Terlingua, Tex.: Bull. U. S. Geol. Survey No. 405, 1909, p. 26.

[2] Idem, p. 25.

[3] Fragments were used that were not parallel to the base, as these would become isotropic at 130°, kleinite being uniaxial, hexagonal.

Effect of heating kleinite.

No. of slide.	Temperature.	Effect.
	° *C.*	
1	177	Doubly refracting; no change.
	187	Doubly refracting; no change.
	194	Doubly refracting; no change. Probably too thick.
2	177	Doubly refracting; no change.
	194	Isotropic.
3	177	Doubly refracting; no change.
	194	Partly isotropic, the remainder doubly refracting as before. The isotropic part, while still transparent, had become brown, the doubly refracting part remaining pale yellow.

It would be premature to speculate on the significance of this observation on the optical behavior of kleinite.

THAUMASITE FROM BEAVER COUNTY, UTAH.

INTRODUCTION.

The interesting mineral thaumasite was first described in 1878 by Baron von Nordenskiöld [1] from material collected at the copper mines of Åreskuta, Jemtland, Sweden. Since that time it has been noted from other localities in Sweden, and in 1896 it was described by S. L. Penfield and J. H. Pratt from Berger's quarry, West Paterson, N. J.

Dr. Edgar T. Wherry, of Lehigh University, has been kind enough to call my attention to a second New Jersey locality for thaumasite. Dr. Wherry writes:

> During the past few years, however, it has been found in considerable amount at another place in the same region, but sufficiently distant to be worth distinguishing—Francisco Bros.' quarry at Great Notch, 3 miles southwest of Paterson. It has been taken so as a matter of course that it should be found there, that nobody appears to have taken the trouble to call particular attention to it, and I can only find two published references, both in out-of-the-way places:
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> Papke, Hermann, A visit to the mineral localities at Paterson and Great Notch, N. J.: Mineral Collector (N. Y.), October 15, 1908, p. 118.
>
> Levison, W. G., On the origin and sequences of the minerals of the Newark (Triassic) igneous rocks of New Jersey: Bull. New York Mineralog. Club No. 2, Dec., 1909, p. 23.

During the summer of 1909, Mr. B. S. Butler, while engaged in a geologic survey of the Frisco district, Beaver County, Utah, found a mineral of unusual appearance which on examination in the office proved to be thaumasite. The mineral was found in the old Hickory mine of the Majestic Copper Co., located in the Rocky Range, Rocky district, Beaver County, Utah, about 4 miles northwest of the town of Milford, which is on the San Pedro, Los Angeles & Salt Lake Railroad.

GEOLOGIC OCCURRENCE.

Mr. Butler describes the geologic occurrence as follows: [2]

> The Rocky Range is composed at the southern end, where the mine is located, of a series of interbedded dolomitic limestones and quartzites of probable Carboniferous

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[1] Compt. Rend., vol. 87, 1878, p. 313.

[2] Butler, B. S., and Schaller, W. T., Thaumasite from Beaver County, Utah: Am. Jour. Sci., 4th ser., vol. 31, 1911, pp. 131-134.

age which have been intruded by monzonite. The intrusion of the monzonite has produced typical contact alteration of the limestone, resulting in the formation of magnetite, garnet, and pyroxene, with some pyrite and chalcopyrite. At the Old Hickory mine the limestone for several feet from the contact has been largely replaced by magnetite with a small percentage of the contact silicates and sulphides of iron and copper. As the distance from the contact increases the amount of magnetite decreases and the contact silicates become correspondingly more abundant, and these in turn give place to the carbonates composing the limestone. The zone of magnetite carrying copper values as chalcopyrite and secondary alterations of this mineral (covellite, chalcocite, and copper carbonate) has furnished the ore that has been shipped from the mine. In the general vicinity of the mine, and especially to the north and northwest, there are veins from a fraction of an inch to upward of a foot in width, composed of a dense white material with conchoidal fracture that on analysis proved to be composed largely of magnesium carbonate with some calcium carbonate. These magnesite veins, however, were not observed in the Old Hickory mine.

The Old Hickory mine has been developed to a depth of about 300 feet and four levels have been opened. A vertical shaft extends to the lowest level, while the second level, about 100 feet deep at the shaft, is connected with the surface by a tunnel. The first level is about 80 feet below the surface and about 20 feet above the tunnel level. On the first level the magnetite body has been opened for a distance along the strike of about 125 feet. To the east of this, a distance of from 10 to 25 feet from the magnetite body, a parallel drift has been run in the altered limestone. One hundred feet south of the shaft a crosscut from this drift extends to the east about 25 feet, where it encounters quartzite. Throughout this eastern drift and crosscut are a great number of veins of white material varying from the thickness of paper to upwards of two inches. To the north of the crosscut many of the veins are open, the crystals projecting into the openings, while others are composed of a dense white substance. The material from these veins proved on examination to be a mixture of quartz and carbonate, the latter probably largely calcite. In the east crosscut, just east of the drift and extending across the drift to a crosscut on the opposite side, is a zone of veins having a general northeast-southwest direction, though the individual veins vary in direction and are connected by crossveins, making a network. These are composed of thaumasite completely filling the fissures.

The fissuring occurred later than the contact metamorphism of the limestone, and the filling of the fissures with thaumasite of course occurred at a still later period. The thaumasite was not found associated with the quartz and carbonates in the same veins, and the relative age of the minerals was not determined. At the Paterson occurrence the thaumasite is in trap, associated with heulandite, apophyllite, laumantite, pectolite, chabazite, scolecite, and natrolite, the thaumasite crystallizing later than the zeolites. No zeolites were found associated with the thaumasite at the Old Hickory mine, though these were especially looked for. It seems probable, however, that the mineral was found under physical conditions similar to those favorable to the formation of zeolites.

PHYSICAL CHARACTER.

In the hand specimen the thaumasite from Beaver County is a nearly pure white mineral with a silky luster due to its fibrous character. It is readily recognized in the field as an unusual mineral by its luster and low specific gravity (1.84). Under the microscope it is seen to be composed of minute slender prisms, none of which showed any terminal faces. Microscopically it is most readily distinguished by its low index of refraction and rather high double refraction; $\omega = 1.507$, $\epsilon = 1.468$ as determined by Lévy and Lacroix. The indices of refraction for the Beaver County occurrence were approximately determined by Butler by immersion in solutions of known index as $\omega = 1.500+$, $\epsilon = 1.464+$. The mineral extinguishes parallel to the elongation of the prisms and is probably hexagonal, as it has been found to be in the previously described occurrences. Crystals suitable for measurement and careful determination of the refractive indices were not found.

CHEMICAL COMPOSITION.

A determination of the density of the thaumasite by means of the Joly balance gave the value 1.84. A second determination, using the Thoulet solution and small fragments of the mineral, gave the value 1.85. These figures are slightly lower than those found by Penfield (1.88) on the New Jersey thaumasite.

The analyses of the Utah thaumasite, with the ratios deduced therefrom, are shown below:

Analyses and ratios of thaumasite, Utah.

	Per cent.	Ratio.		
SiO_2	10.14	0.169	1.06	1
SO_3	12.60	.156	.98	1
CO_2	6.98	.159	1.00	1
CaO	26.81	.479	3.00	3
H_2O	42.97	2.387	14.95	15
$(Al, Fe)_2O_3$	.20	.002		
MgO	.23	.006		
Alk.,P_2O_5	Trace.			
	99.93			

The ratios agree very closely with the established formula $3CaO.SiO_2.SO_3.CO_2.15H_2O$, and the mineral is very pure, only a trace of some foreign matter—probably a silicate—being present.

A comparison of the analyses of the mineral from Utah, from New Jersey, and from Sweden (the average of the three original analyses given by Lindström) strikingly shows the uniform composition of this rare mineral.

Comparison of analyses of thaumasite.

	Jemtland, Sweden.	New Jersey.	Utah.	Theoretical composition.
SiO_2	9.70	9.26	10.14	9.64
SO_3	13.02	13.44	12.60	12.86
CO_2	6.86	6.82	6.98	7.08
CaO	27.28	27.13	26.81	27.01
H_2O	42.20	42.77	42.97	43.41
$(Al,Fe)_2O_3$	.16		.20	
MgO			.23	
Na_2O	.11	.39	Trace.	
K_2O	.08	.18		
P_2O_5			Trace.	
Cl	.12			
	99.53	99.99	99.93	100.00

The new locality in Utah makes the third general locality in which this mineral has been found, or the fifth distinct mine, the three localities in Sweden being fairly close together.

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THE IDENTITY OF STELZNERITE WITH ANTLERITE.

Stelznerite was described as a basic copper sulphate by Arzruni and Thaddéeff[1] in 1899, their paper being edited by A. Dannenberg on account of the death of Arzruni. Prof. F. W. Clarke has recently called my attention to the chemical identity of stelznerite with a mineral analyzed by Dr. W. F. Hillebrand and named antlerite.[2] I have extended the investigation by examining optically some of the original type material in the U. S. National Museum, for which privilege I wish to acknowledge the kindness of the assistant curator, Dr. J. E. Pogue. All the facts ascertained point to the identity of stelznerite with antlerite.

Antlerite, under the microscope, was seen to consist of a homogeneous aggregate of very minute crystals of short prismatic habit and of pale greenish color. The crystals extinguished parallel but were too small for any determination of their optical orientation. The small crystals were not perceptibly pleochroic, but on the thicker ones a decided pleochroism was noticed, identical with that described for stelznerite.

Parallel to the elongation of the crystals, the color was blue green; normal thereto the color was yellow green. The double refraction is high. These data are all in accord with those given for stelznerite. The values of the density, 3.93 (antlerite) and 3.884 (stelznerite, not corrected for admixed gypsum) agree closely.

Chemically the two minerals are also seen to be identical, as was first noted by Prof. Clarke. The formula deduced for stelznerite is $3CuO.SO_3.2H_2O$, or $CuSO_4.2Cu(OH)_2$, while Hillebrand calculated the more complex one, $10CuO.3SO_3.7H_2O$, or $3CuSO_4+7Cu(OH)_2$, for antlerite. The analyses of antlerite are compared with those of stelznerite in the table below. Nos. 1 and 2 are Hillebrand's analysis of antlerite, with 8 and 6 per cent, respectively, of gangue deducted, and Nos. 3 and 4 are the analyses of stelznerite. The fifth column gives the calculated composition for the formula $3CuO.1SO_3.2H_2O$ and the sixth that for the more complicated formula $10CuO.3SO_3.7H_2O$.

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[1] Arzruni, A., and Thaddéeff, K., Neue Minerale aus Chile; Stelznerit, ein neues basisches Kupfersulfat: Zeitschr. Kryst. Min., vol. 31, 1899, p. 229.

[2] Hillebrand, W. F., Mineralogical notes; 6. A basic cupric sulphate: Bull. U. S. Geol. Survey No. 55, 1889, pp. 48–54. Also given in Dana's System of mineralogy, 6th ed., 1892, p. 928.

Analyses and calculated compositions of antlerite and stelznerite.

	Antlerite.		Stelznerite		$3CuO.SO_3.2H_2O$.	$10CuO.3SO_3,7H_2O$.
	1	2	3	4	(Calculated.)	(Calculated.)
CuO	68.19	67.64	67.08	64.01	67.22	68.45
SO_3	20.46	21.49	22.40	22.19	22.61	20.69
H_2O	11.11	10.76	10.22	10.37	10.17	10.86
ZnO	.29	.04				
CaO	.05	.04	.06	.57		
Fe_2O_3			.34	1.14		
Residue			.44	1.42		
Moisture				.33		
	100.10	99.97	100.54	100.03	100.00	100.00

Though the first analysis of antlerite agrees better with the more complex formula, the second analysis agrees as well with the simpler stelznerite formula. As no certain differences could be found in the optical properties and as the analyses agree so closely with one another, the two minerals stelznerite and antlerite must be considered identical.

The characterization given stelznerite is much more complete than that of antlerite, and the formula deduced, $CuSO_4.2Cu(OH)_2$, is also simpler and is doubtless the correct one for the species. The name antlerite has, however, priority by 10 years, and is the one to be adopted.

On careful investigation antlerite will doubtless be found to be much more abundant than is now thought, and much of what is now called brochantite may be found, on analysis, to be the closely related antlerite. The artificial brochantite, described by Dana,[1] is more likely antlerite.

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[1] Dana, E. S., System of Mineralogy, 1892, p. 926.